INDUSTRY AND SCIENCE

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A study of their relationship based on a survey of firms in the Greater Manchester area carried out by the Manchester Joint Research Council, 1950–1953

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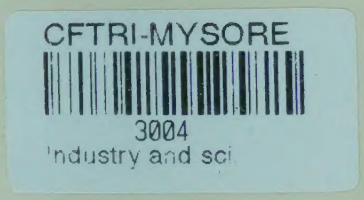

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The death of Mr. Butchart, who had so successfully led the team and worked so devotedly on the preparation of the Report, was a serious setback as well as a personal loss to the members of the Council. Sir Raymond Streat, as Chairman of the Steering Committee, had given invaluable impetus and guidance throughout and the Council is indeed grateful to him for undertaking, at this critical stage, the re-writing of the Report. Contributions of special value were also made to the actual preparation of the Report by Mr. Ainsley and Professor Devons, and by Professor Thompson who read and revised the final text.

The Council also thanks the firms who, through their financial support, gave it an opportunity of seeking similar assistance from the Department of Scientific and Industrial Research, whom it equally thanks for highly valued co-operation and support throughout.

The Report itself makes clear our indebtedness to the 225 firms through the co-operation of whose Directors and Staff the Survey was alone made practicable.

G. P.

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CHAPTER I

THE ORIGIN AND SCOPE OF THE INVESTIGATION

In recent years, as perhaps never before, leaders of thought and action in Britain have been concerned about the relationships between science and industry. The impact of science on every aspect of life in this country during the first half of the twentieth century has been profound and dramatic. Practical applications of scientific knowledge have revolutionized communications, materials, medicine and, hence, many of the conditions of our social life. Because of this revolution many things of importance both to Britain as a country, and to individual Britons as human beings, have changed significantly, and are still changing. The defence and security of the realm presents problems to-day which the Victorians would have regarded as fantastic, whilst the country's task of earning its keep by agricultural and industrial production is now determined by factors so different from those which obtained a hundred years ago that we might be living on a different planet from that on which our grandfathers made their mark.

It is generally acknowledged that British scientists have contributed an outstanding share of the theoretical, and very many of the practical, advances which have enlarged the frontiers of knowledge, and have thus made possible the scientific revolution in human society for which this century seems likely to be memorable. In the second world war, British scientists and industrialists combined to produce devices and weapons which enabled our defences to hold against aggression, and then made possible the success of the allied counter-attack. As soon as the war was over, however, thoughtful people in government circles, in the universities and in industry began to ask whether the contacts and mutual

relationships between science and industry were in fact satisfactory in the new peace-time conditions in which Britain would be compelled to utilize her resources, human, scientific and industrial, to the full to maintain herself fittingly in the post-war world.

It has been a characteristic feature of British life and thought to indulge in self-criticism, and often to do so in public to an extent which almost amounts to self-denigration. Britain's friends, as well as her enemies, have been misled from time to time by this national trait. Rather curiously, this taste for self-criticism exists side by side with an innate and deep-seated confidence in the strength, health and staying power of the British community. There are optimistic spirits amongst us, animated no doubt more by the second of these two habits of thought, who have dismissed these doubts regarding the interaction of science and industry with a cheerful conviction that Britain would, somehow or other, render a satisfactory account of herself. Others have felt that the issues involved were too complex, and certainly too grave, to be dismissed without more serious thought. As a result, there have in the years since the war been almost innumerable pronouncements, inquiries and reports by various government agencies, by organizations like the Federation of British Industries, the Parliamentary and Scientific Committee, the Anglo-American Council on Productivity, by various scientific bodies and by individuals. The balance of opinion throughout has been that modern conditions called for more to be done in Britain than has so far been done, and the problem has increasingly veered towards the question of what precise action is required, rather than whether anything at all is necessary.

The Manchester Joint Research Council

In the year 1944 the Manchester Joint Research Council was established as a co-operative effort between the University and the Manchester Chamber of Commerce. The idea of

forming such a body was partly a reflection of the questionings on the subject of science and industry which were already making themselves heard throughout the country. The University and the Chamber of Commerce agreed that they would be performing a public service in setting up such a Council, composed in equal parts of representatives of the University, speaking for scientists and science from the academic angle, and representatives of the Chamber of Commerce to speak for industry and commerce. Manchester is the centre of one of the largest and most diversified industrial areas in the world, and the achievements both in research and teaching of Manchester University's science and technological departments have received world-wide recognition. It seemed eminently proper, therefore, to take advantage of this position and to establish such a joint body in the hope that, by conferring together, they might find an opportunity for fruitful service to the community in general, and more particularly to the local industries. The Council immediately found an increasing field of usefulness within its scope and resources. It opened a liaison service, appointing a whole-time Executive Liaison Officer, himself with both training and experience in industry and science. It organized lectures and discussion meetings to spread ideas and understanding concerning one or other of the many aspects of the relations between science and industry. It printed reports of these and made them available to those concerned.

Towards the end of 1948 and during 1949 the idea gradually developed that the Manchester Joint Research Council might be able to render a particularly useful service if it conducted a special sort of investigation into the use which is made of scientific knowledge by the industries in the area. There was nothing new in the notion of organizing inquiries amongst industrial concerns ; several such had already been made by bodies or individuals which had led to valuable reports or publications. But, so far as the Council knew, no attempt had previously been made to do so by personal interviews with the heads of a large number of firms in several

representative industries. Earlier inquiries had, at any rate in the main, relied on written questionnaires or upon the testimony of a relatively small number of industrialists. The Council's idea was to take a well-selected and representative cross-section of the firms in the thickly populated industrial area in and around Manchester and to pursue the subject by means of confidential conversations conducted by a small team of well-chosen investigators. The project was discussed with distinguished scientists and industrialists who attended meetings of the Council, and in due course a plan was laid before the, then, Lord President of the Council, Mr. Herbert Morrison, as the Minister responsible for the Department of Scientific and Industrial Research. Mr. Morrison and his advisers gave the Council emphatic encouragement and the Department of Scientific and Industrial Research subsequently undertook to make a grant towards the cost of the enterprise, pound for pound of any sum which the Council could raise from its friends in industry.* An appeal was launched, with the result that in a few months approximately £4,000 was raised. This response not only provided the Council with the necessary financial resources, but also demonstrated that they were not alone in thinking that it would be a good thing to determine the facts and set them down for general consideration.

It was then the end of 1950, and the Council was able to appoint two men, both having some knowledge of at least one branch of science and with mature experience of industry, to make, with their Executive Liaison Officer, a team of three to carry out the investigation. A Steering Committee was appointed to guide the work of the investigators, and the first two or three meetings were sufficient to emphasize in the minds of all the members that there was plenty of scope for such guidance. Discussion revealed that there were dangerous pitfalls to be avoided : ask the wrong questions and wrong answers will be received ; ask the wrong people and the answer will not be representative or will lead the

* Up to a limit which was not in fact required.

inquirers astray; ask in the wrong way and the friendly communicativeness of the industrial contacts on which the entire project depended will never be secured.

The Object of the Investigation

It speedily became clear to the Steering Committee that they must establish in their own minds what exact problems they were trying to examine before they could decide what questions to ask to throw light on those problems. Much time and thought were given to this vital issue and eventually agreement was reached as to the problems which would provide a desirable basis for the inquiry. This agreed basis, which constituted a framework for the investigation, is also a framework for this Report, and, if the reader is to appreciate fully the significance of the Report as a whole, he must keep this framework in mind.

It was decided to start by accepting the view, *for the purpose of this inquiry*, that new scientific and technical knowledge is absorbed into certain sections of British industry too slowly, and that a scientific approach to the day-to-day problems of production and organization is less common than it should be. Many of those best qualified to form a reliable judgment will consider that this view is mistaken, but there is no question that it is held. It appears regularly in the Press, on the radio and in innumerable reports, official and unofficial; it is indeed often accepted as true without any further need for verification. The investigators were not to be primarily concerned to discover whether this opinion was right or wrong, although it is thought the facts collected will throw some light on the question. They were to be interested rather in exploring the reasons usually given why Britain is supposed to lag behind in this way. Here there is a wide diversity of views, but a few themes recur regularly and it is to these that it was decided to devote most attention.

One of the main reasons, put forward with increasing frequency in recent years, for the alleged backwardness of British industry in this respect, is the relatively small number

of scientists employed in industry. It is usually implied that this is due to a combination of the inadequacy of the facilities for training scientists on the one hand, and to industry's unwillingness to employ them on the other. Some put less emphasis on the insufficiency of the total supply of scientists, but argue that they are not of the right type ; that what industry really needs is more men trained in technology and engineering with a special knowledge of industrial processes, and has less use for the pure scientist. It is this view that lies behind the demand that the study of technology and engineering should be expanded at the universities and that perhaps special technological institutes, or even a special technological university, should be founded.

Alternatively it is argued that industry does not make the best use of the scientists that it does employ. The real trouble, it is asserted, is that scientists are confined too narrowly to research organizations and to the research departments of firms, and that there would be a radical change for the better if industrialists would also employ scientists in production and in management up to the highest level. The nation could then be sure that the scientific view would have real influence, resulting in a more ready adoption of new ideas and the use of scientific methods in day-to-day production and organization. Others disagree with this view and claim, without in any way wishing to underrate the place of the scientist in industry, that the way to get initiative, enterprise and up-to-date methods in any firm—whether it uses science or not—is to find the man with " fire in his belly " who is passionately absorbed in improvement and innovation, and that there is no reason to believe that the scientist has more of this fire than his non-scientific colleague. If this argument be well founded, the essential issue is how to recruit and encourage such enterprising innovators ; and on this view, increasing the number of scientists in industry, although perhaps desirable on other grounds, does not necessarily meet the fundamental problem.

The Steering Committee were never under the illusion that

this inquiry, by itself, could provide a conclusive answer to these arguments ; but these different views are so often put forward—frequently with little or no supporting evidence—that it was felt that some facts regarding the employment of scientists in industry might help to throw light on the question, if only indirectly. It was agreed to try to find out, therefore, how many scientists were employed by each firm ; what were their qualifications and what was their industrial experience ; how many were employed in research and development as compared with those in production or with other activities of the firm ; and how many were employed in higher management and had a seat on the board of directors. The investigators were, further, to be ever watchful for any signs which might indicate whether the employment of scientists of a particular type, or in a particular way, seemed to lead to a progressive atmosphere in the firm. They were also to endeavour to discover whether having scientists at the higher level of management and on the board of directors led to any crucial difference in the attitude and practice of the firm.

The Universities, Research Associations and Industrial Research Departments

Sometimes the explanation of the alleged backwardness in British industry is assumed to lie not so much in faults concerned with the employment of scientific personnel, as in weaknesses in the organization of research and development and in their relation to production. Here there are three main questions. First : are the existing institutions which provide the basis, directly or indirectly, for industrial progress in research sufficient to meet the needs of industry ? The three main types of research organization at present are the universities, the research associations and the research and development departments of the firms themselves. Are these sufficient to cater for all requirements, or would more research and development be undertaken if firms could get specific research undertaken for themselves exclusively and for which

they would pay? In other words, is there a need and a demand for new institutions to undertake sponsored research?

Next come all the questions regarding the use of the existing institutions. What should be the rôles in industry of the universities, the research associations and the research departments, and how are the functions which they perform related to each other? The significance and relevance of these issues clearly varies from industry to industry, and even from firm to firm within an industry. A large firm in an industry subject to rapid technical change, with a large research and development department of its own, would expect quite different services from a research association as compared with a small firm without research facilities of its own and in an industry where technical change is slow. Indeed, it was soon discovered that to pose such problems as "the universities and industry" or "the research associations and industry," as if they were uniform for all industries and all firms, was misleading and, in fact, likely to lead to a confusion rather than a clarification of the issues involved.

Thirdly, there arise the problems of the rôle of the research and development departments in the firms themselves, and the relation of these departments to other branches of the firm. How valuable are such research divisions? Are the firms that have them usually in the front rank of industrial progress, or does substantial progress often take place, either of a spectacular nature or by the day-to-day accumulation of smaller improvements, in firms that are not so equipped? Is it true that there is often great difficulty in getting new ideas adopted in production even where rapid progress is being made in the research and development division of the firm? If so, is this due to some weakness in the organization of the firm, or can the difficulty be overcome, as was suggested earlier, by employing scientists in production and giving research scientists industrial experience?

It will be seen that although the second set of issues arise as problems of organization and institutions, they are not unrelated to the first set about the employment of scientists

in industry. There are numerous overlaps of this kind between these different ways of looking at the problem. Two may be mentioned as examples. Does the employment of scientists by industry result in closer contacts between industry and the universities? Would the employment by the research associations of scientists with industrial experience lead to a better appreciation by the associations of the needs of industry? The first series of questions about the employment of scientists in industry must, it seemed, be related to any information which could be gathered throwing light on the second set of problems about organization and institutions.

The next series of questions were designed to throw further light on these issues. Questions were to be asked about the size and character of the research and development division in the firm; the type of work it did—whether fundamental research or substantial or minor development; the relation between research, development and production; contacts with universities; how often the research association was consulted and on what issues; and what other sources of scientific information were used. The investigators were to encourage free expressions of opinion, whether critical or favourable, about the adequacy of existing facilities and they were to ask all firms specifically whether they would welcome the setting up of institutions for sponsored research and, if so, whether they would use them.

The information obtained is discussed in the chapters which follow. Although it is convenient, and perhaps unavoidable, to divide the subject up into chapters, it cannot be emphasized too strongly that the issues raised in each chapter are very closely related to those discussed in the others. The various forms of scientific and research organizations must be regarded as providing closely interrelated and complementary services, the nature of the interrelation varying with the different circumstances of each industry and firm, whilst the employment of scientists in industry has an obviously close connection with that industry's structure and organization.

The Steering Committee and the investigators agreed in

the preliminary discussions to define and limit, in the way just described, the problems on which it should be the object of the inquiry to throw light. They were, it need hardly be said, fully aware that such treatment by no means covered the entire field and that it might even leave out some highly important aspects. An important set of questions which were purposely put on one side ought perhaps to be specifically mentioned. Many people argue that the lack of a scientifically enterprising spirit in industry is due to government control over industry, to restrictive practices by industry and labour, and to the general level of taxation. It is said that these make enterprise difficult, and in many cases unprofitable. It seems necessary to make quite clear that no opinion is expressed or implied one way or the other in this Report about the validity of these arguments, and while not underrating their importance, the Steering Committee have not attempted to deal with them in any way.

The Field of Inquiry

The area covered by the survey is shown in the map facing page 188. This geographical limitation is inherent in all the work to be recorded, and it is to the industry of this region only that the data collected directly refer.

Having described the framework of the inquiry, it now seems desirable to give some particulars concerning the mechanics of the operation. In order to ensure that the firms interviewed should be truly representative of industry in the area, it was first necessary to obtain a picture of the industrial units in the region and their distribution. It seemed necessary to examine the number of firms in the various types of industry, how they were divided in respect of size, and many other details. In this task, as in all their work, the investigators received constant and unstinted help from the Department of Scientific and Industrial Research and from the Board of Trade.

A study of the Standard Industrial Classification List estab-

lished by various government departments for such purposes as the Census of Production, suggested that this would provide the most useful basis available for a survey of the field. Particularly was this so since it was also possible to obtain from government records information as to the number of establishments in each section of industry and also of the number in each size-category in the various sections.

In order to render their task at all possible the Committee realized that some limitation of the field of inquiry was essential, and it was decided not to include firms engaged in certain sections of industry on the ground that their experience would not be immediately relevant to the purposes in view. Some of the decisions to exclude certain activities were easy and obvious, some clearly more doubtful or even controversial. Headings in the Standard Industrial Classification appearing as "Public Administration" and "Professional Services" fell out at the first winnowing. Agriculture and distribution were omitted as being outside the province of this investigation. The clothing industry seemed to be a field which could reasonably be left alone and the building trades, so far as the description relates to pure building contracting, seemed unlikely to justify inclusion. The coal-mining industry, the gas, electricity and transport industries had been nationalized and it was felt to be inappropriate to approach them on the subject of the investigation. When all these decisions had been taken there still remained a vast field which embraced ceramics, the chemical trades in all their manifold ramifications, the production and fabrication of metals, all the numerous sections of the engineering industry on both the mechanical and electrical sides, textiles, again with many distinct sections, tanning and leather products, the food, drink and tobacco processing industries, wood, paper, rubber, linoleum and plastics.

It was further decided that firms employing fewer than fifty persons would, in general, have little of interest to say, at any rate nothing that could not be gathered from talks with slightly larger firms. If only firms employing fifty or

more were selected for interviews, it was felt that a rational simplification of the task would be achieved without any loss of significant evidence.

In view of the many surveys already carried out by other bodies, such as the Federation of British Industries, on subjects of a nature akin to that now being discussed, it was also decided to omit from this work the very large firms with country-wide ramifications. These have already been adequately covered elsewhere and particulars are freely available in the reports issued.

A distinction must also be made between establishments and firms. An establishment is a single "factory," self-contained in most respects, usually under separate works management, but possibly one of several such factories belonging to the same firm and responsible to one board of directors. There are quite a number of multi-establishment firms in the area—some firms have actually over fifty establishments and many have two or three—a fact which affords an explanation of the apparent anomaly of the survey having covered over 500 establishments whilst having dealt with only 225 firms. When reference is hereafter made to "firms," these considerations should be borne in mind. That the appreciation and application of science by a particular establishment will be in line with that of the parent firm can normally be taken for granted, while a parent firm's research department and scientific service may be assumed to be feeding each establishment to a more or less similar degree. This is principally important for statistical purposes, so that when numerical comparisons are made proper weight will be given to the elements compared.

The investigators decided at an early stage that it would simplify their report, and in particular make any comparison or facts they might wish to record more truly relevant to conditions within industry, if they could group the firms to be approached in certain broad classifications within which at least some common factors might safely be assumed to exist. For instance, in Lancashire they must obviously explore the

views and experiences of firms connected with the textile industry ; the textile group then would form a clear, separate unit. Equally obvious was the engineering group. At that point, however, the obvious groupings seemed rather suddenly to be exhausted, and the investigators had to make a somewhat arbitrary decision to form two more groups. One they called the " Modern Industries " group. They would not like to be challenged to give a definition so precise as to stand examination in a court of law, but, broadly, they had in mind those industries making materials or articles which were unknown to society or industry a hundred years and, in many cases, even fifty years ago, and which had since become familiar largely because of the extension of scientific knowledge, together with some industries like paper, which, though certainly old, are in their modern form dependent on a scientific background. Electrical engineering, too, is of recent origin, and the decision to include this industry in the modern group leaves mechanical engineering to stand alone. Rayon production, too, was grouped with the modern industries rather than with textiles. The last group was termed " Miscellaneous Industries," not so much because it had to accommodate the undesignated remainder, but because the industries within it did not share, as did the firms in the other three groups, at least something in the way of common problems and common needs. They were too small to stand alone, and too diversified to have common characteristics.

In Appendix 1 will be found a statement of all the industries investigated under the names used in the Standard Industrial Classification, and as finally divided into these four groups.

Of the firms in the textile industries group, visits were planned and eventually made, which covered 20 per cent. of the establishments in the area. Firms in the engineering industries visited covered 17 per cent., whilst for the so-called modern industries the comparable figure is 22 per cent. and for the miscellaneous industries 23 per cent.

Sampling and Weighting

One important reason for using these classifications will now be apparent. It seemed necessary to make sure that the importance of the textile and engineering industries, for example, did not unduly colour the survey to the exclusion of others, and the figures just quoted seem to afford satisfactory proof that any such danger has been avoided.

The selection of firms from several lists available was as genuinely a random selection as the investigators could achieve. Nothing influenced the selection except the factor of size of firm, and this consideration was taken into account only to the extent of making sure that firms of different sizes were fairly evenly represented. It was clearly realized that anything other than a truly random selection might seriously distort the picture. For example, had a Professor of Chemistry been asked to select firms in the chemical industry, those which would spring to his mind would tend to be active collaborators with his university or making products often considered in his teaching or research, and the investigators might as a result have been badly misled as to the degree of collaboration with universities which generally prevailed.

Samples of the magnitude which have in fact been achieved, when selected at random, ought to yield information which is reasonably accurately representative of the whole body, and such facts as can be recorded statistically, and the comparisons founded on these facts are set out in this Report or in Appendix 1 in this belief. The only doubt which continued to trouble the Steering Committee was whether the picture obtained might in some respects have been unduly affected by two factors. Some firms included in the random selection declined to receive the investigators and to answer their questions. If all the firms which so declined were in fact amongst the most backward in their use of science, the picture drawn in this Report will to that extent be too favourable. There is, however, no such evidence as to the average state of backwardness or progressiveness amongst the firms who

failed to respond. The second of the factors giving rise to some doubt arises as regards the area of the investigation. It is quite possible that in the area chosen, later described as Greater Manchester, a larger percentage of firms might have contacts with scientists and scientific bodies than in a wider area. In textiles, for instance, convenient proximity to Manchester might over the past twenty years or more have made it more likely that firms would have scientific contacts. If the picture presented is made slightly more favourable on account of the influence of such a factor on the firms selected for interview, it is not believed that it is likely to make the comparisons seriously misleading.

By the early spring of 1951, sufficient progress had been made with all this preparatory work to start despatching requests for interviews and these began to be sent out in a steady flow. The text of the letter signed by the then Chairman of the Council is of sufficient interest to bear reproduction. It was addressed to the chairman or managing director of each firm, and ran thus :

On behalf of the Manchester Joint Research Council I am writing to ask you to see one of our liaison officers and to discuss with him whether you would be disposed to collaborate with the Council in an investigation which we believe should bring good practical results for industry. The complete story of our project is better told verbally, but I will give you a brief indication of our objectives.

We have set ourselves the task of assembling a reliable picture of the use of science by a cross-section of industry in the north-west. Everybody acknowledges in a general way that fundamental scientific work in Britain to-day is second to none in the world. It is realized, too, that as conditions of intense world-wide competition return, national prosperity will depend on our ability to maintain a lead over all comers and that we must utilize fully the power and advantages of science. What is not so clear is precisely how the fullest possibilities of science can be absorbed into industrial practice more rapidly and widely.

The question constantly arises whether the grants made by the Government produce good results and whether there are any gaps

in the existing scientific facilities which could be filled to advantage. A picture of what actually happens in a representative area in Britain should help business men and scientists to see more clearly what could best be done to increase the use of science in productive industry.

Two strong recommendations for our project are that the members of the Council are unanimously behind it and that the directors of the Manchester Chamber of Commerce have given it their full approval.

A sufficient expense fund has been forthcoming from contributions by a number of supporting firms and from the Department of Scientific and Industrial Research, which has shown a keen and most encouraging interest in the idea.

I enclose a list of our members, all of whom, along with our financial supporters, believe there are real prospects of achieving worth-while results.

Previous efforts to shed light on these matters have relied mainly on the written questionnaire—often very elaborate and inapplicable to a particular firm. *We* are relying on personal talks by our liaison officers which will enable us to give, as well as get, information which would, of course, be entirely confidential and so treated by our investigators.

If, as the outcome of our contacts with your company, there emerge points on which you want information, we will endeavour to find the right answer so as to reciprocate your courtesy in co-operating with us. Our experience so far suggests that in this way immediate benefit may arise quite apart from the value of our study of the general question.

The Council members will greatly appreciate your agreement to see our representative for a preliminary talk. On hearing from you to that effect, a convenient appointment will be arranged without delay.

The response to this letter, about twenty copies of which were posted at intervals of a few weeks, was immensely gratifying to the Council ; 76 per cent. of the firms approached replied agreeing to a visit from one of the investigators, and a start was made on the interviews.

Interviews

The first dozen of such interviews were necessarily of an exploratory character, and they were in the main chosen deliberately from amongst those firms who were known to be sympathetic to the aims in view—perhaps because they had subscribed to the fund or had in some other way indicated their interest in what was being attempted. Nevertheless, it was with a certain amount of trepidation that the investigators set out to put to test the routine which they and the Steering Committee had evolved and which they believed would lead them to their goal. As far as was known, there were no precedents to guide them and, apart from the *aide mémoire* which had been devised to assist them in keeping their objectives clear in their minds whilst they were engaged in conversations, they had to rely on their own initiative so to interest executives and administrators as to ensure that information should flow freely. It was not for them to lay down how the talks should proceed. They had a number of factual questions to which they wanted answers if the man who was receiving them proved willing to give them, but they also wanted to hear what he might feel an impulse to say regardless of whether or not it touched on any of their prearranged headings for inquiry. They were, indeed, almost more interested to discover his unprompted reactions to the relationships between his business and science than in their own questions.

As the three investigators reported almost daily to each other, and at frequent intervals to the Chairman of the Steering Committee, certain general reactions emerged, some conforming to their expectations but some which had not been anticipated. The manner of their reception illustrated not only the infinite diversity of human psychology and temperament, but also an equal variety in the ways in which business men conduct the internal affairs of their concerns. Sometimes their first talk was with the chief executive alone ; sometimes he gathered two or three of his colleagues for a round-table chat. There were many cases in which the investigators were

introduced to other officers of the company, perhaps the head of the research department or the production manager, and placed fully at liberty to talk with him. Often the investigators were themselves plied with quite as many questions as they asked, not only concerning the reasons behind the inquiry, but about a wide variety of scientific and technical problems. They would be asked what they had to say about some problem which their *vis-à-vis* had encountered but never completely solved, or they would be invited to comment on what their host obviously regarded as a source of obstruction to the aims and ambitions of his firm whether the fault was laid at the door of the government, the educational system, the supplier of materials, or the unenlightened customer !

From all this, as from the favourable reception given to the first letter asking for the investigators to be received, there emerged the predominant impression that industry in the Greater Manchester area is very much alive to the existence of a real problem—and a vitally important one—in the relationships of industry and science. Others may criticize what industrialists actually do about it, but on the experience of the investigators it is not true to say that industry is unaware of the problem.

How far this Report will help industry or government, or the world of science, to discover favourable and feasible avenues of progress only time will show. It will be clear that neither the nature of the sample nor the method of inquiry which has been adopted will make it possible for the Manchester Joint Research Council to offer final conclusions regarding the important problems defined earlier in this chapter. It is the hope of the Council, nevertheless, that this work has resulted in something which may be of real value.

If the reader will study the chapters which follow, in which he will find a record of the facts which have been elicited about the distribution of scientists and technologists ; the existence of internal research and development activities within the firms visited ; the contacts between industry and the

universities, between industry and the research associations, and the use made by industry of other sources of scientific information, he will find a factual examination of these questions which may do something to clear up many widely prevalent misconceptions.

Often enough, speakers and writers refer to "*the* problem of science and industry" as if there were but one single and similar problem for all industries and for all firms, and as if remedies could be applied blanket-wise for the whole of the British economy. This Report demonstrates how wide is the variety which exists in the circumstances and problems facing our industry and hence reveals such an approach as entirely unprofitable. The survey, in the view of the Council, has clarified the real nature of the problem of science and industry, and if it helps to point the way to further lines of fruitful investigation and possibly, in some directions, even to immediate action, it will have served its purpose. The succeeding chapters should be read as an explanation of how the problems outlined appear to have been clarified as a result of the investigation, rather than as a set of definitive answers to the underlying questions. Nothing can be done to dramatize material of this kind, but it is hoped that the patient reader, whether industrialist, scientist or research director, will find facts which will set his mind working creatively on his own particular problems. For those who may wish to examine in closer detail the facts which have emerged, the data obtained and their statistical analysis are provided in Appendix 1 to this Report.

CHAPTER II

THE EMPLOYMENT OF SCIENTISTS AND TECHNOLOGISTS

In this chapter it is hoped to shed some light on the way industry makes use of the scientists it employs. It has already been remarked that many commentators on the relations between British industry and science freely assert, all too often in the absence of established facts, that management in industry is much at fault in the use it makes of its scientific staff. It seemed, therefore, important to find out how scientists and technologists were deployed by the firms included in the field of this investigation—what were their numbers, and what responsibilities were allotted to them.

It became apparent in the early stages of the inquiry that nothing in the nature of a clear line of demarcation between scientist and technologist existed in industrial circles. Often the investigators found that a man who by his training and qualifications would in their view be rightly classified as a scientist was carrying out duties which they would unhesitatingly have described as the functions of a technologist. The reverse situation was encountered less frequently, but there were fairly numerous instances in which men with a training plainly technological in character were undertaking work which was largely scientific, and sometimes proving themselves very well capable of so doing.

For this, and other reasons, no attempt has been made in this Report to distinguish between the scientist and technologist, both of which are, therefore, included in the general designation " scientist/technologist." A clear distinction may, however, be drawn between the university graduate and the holder of a diploma, and the employment by the firms of these categories of qualified men is a matter which lends itself to exact determination.

The term "graduate," it was decided, should be used in relation to the holder of a university degree in science or technology. A diploma, on the other hand, should cover such qualifications as A.M.I.E.E. and A.R.I.C., but should not include the associateship of a technical college or of certain institutes whose awards are not yet generally recognized by employers in the industry which they serve. It should at once be emphasized that this distinction casts no reflection on the standards set for such associateships, which may well be excellent. A dividing-line had, however, to be drawn somewhere and it seemed that the best way to deal with the data to be discussed was to record only diplomas enjoying unquestioned, nation-wide recognition. It is quite frequently the case that one man may hold both a university degree and a technical diploma. In the text and in the tables in Appendix 1 such men are regarded as graduates and do not appear again as diploma-holders.

Many holders of diplomas, who are not graduates, have gained their qualifications by attendance at evening classes or by other part-time education, while simultaneously absorbing practical experience in employment. Their total training will have had a practical emphasis, while at the same time it has given them a certain range of knowledge in a branch of science or technology associated with the industry which they serve. The education of the university graduate, on the other hand, normally extends over a period of years, during which he is untrammelled by the necessity of carrying out a day's work in addition to his studies. In other respects too his education is often wider and he has the opportunity of going more deeply into the more fundamental principles of his science. During his university career he has the advantage of day-to-day contacts with some of the best scientific brains of the times, and with fellow-students working in many other intellectual fields. He, therefore, has good opportunities of absorbing much that is best in the scientific world, but has generally few or no contacts with industry, and little scope until he leaves the university and takes

up employment, for applying his knowledge to industrial problems.

The directorate of any firm seeking a scientist/technologist will try to select a candidate whose training and upbringing are best suited to what they conceive to be their needs. Since such needs vary, and ideas as to what the requirements are vary still more, it did not surprise the investigators to find marked differences in the preferences shown by different firms in the types of recruits selected. In some cases it was found that the firm preferred to recruit a graduate straight from the university and to give him his industrial experience themselves. They appreciated that it would be some years before he was of full value to them, but preferred to accept this delay and expense in the belief that it would be to their ultimate advantage. Others when seeking a graduate liked to feel that he had already been "broken in" to industry and industrial methods, and considered the ideal recruit for their purposes to be a graduate who had two or three years' industrial experience behind him, as he could then be expected to pull his weight in the firm more quickly. In the smaller firms it was more usual for a preference to be shown for the diploma-holder who had entered the business as a youth and had, by dint of extra-mural studies, pursued sometimes outside working hours and sometimes in the firm's time, qualified for a diploma of one of the professional societies or institutions. It was said by many such firms that this training produced a man of the calibre best suited to their needs in that he had already a practical outlook and understood instinctively that, until its financial success seemed reasonably well assured, any new project must be viewed with caution.

The investigators found that out of the 225 firms visited, 118 (52 per cent.) employed at least one scientist/technologist and that the total force of such qualified men amounted to 1,297—made up of 684 graduates and 613 diploma-holders. If all the firms who refused to co-operate were without such men, and this is not the case, the percentage of firms employing a scientist would be reduced to 40. The posts filled

by these men covered every level from the chairman of the company down to an assistant chemist or engineer in the laboratory or test room, and the numbers found in any particular firm varied from one to over a hundred. The important fact is that in each one of the firms so staffed there was at least one person trained to one or other of the scientific standards defined above. The total labour force in the 225 firms is approximately 147,000 and of these 123,000 (84 per cent.) are employed in firms where there is at least one scientist/technologist.

Scientist/technologists are employed in so many different capacities that it has been found impossible to classify them by the posts they occupy, except in the case of directors. Out of the total of 1,297 there were 128—almost 10 per cent.—who were directors, and these were divided amongst 88 firms, i.e. 39 per cent. of all those visited.

It was found that the investigators could distinguish with reasonable confidence 77 firms who were undertaking development from their own original research and new ideas ; 42 firms relying on established principles for their development ; and 26 in which development consists merely of minor innovations or the adoption of ideas already fully developed elsewhere. Having thus classified the firms, it was possible to see how many scientist/technologists were employed in each group—to which could be added the technologists employed solely for management, process control and testing in the 25 firms whose practice did not go beyond that point. In the classification it was assumed that each category embraced all those of lower standards. For example, a firm which has a research and development department would also be assumed to undertake work based on established principles, together with minor innovations and works testing.

It seemed to the investigators fair to say that when a particular firm undertakes research work of a high quality, every scientist/technologist in that firm will, either directly or indirectly, come into contact with work at that level, even though he himself is in some other department. This has its influence

on his general outlook, and hence on the manner in which he carries out even his routine duties.

By far the greatest number of qualified men were found in those firms in which research, and development from new knowledge, is undertaken. No fewer than 1,021 of the total 1,297 are employed by the 77 firms in this class. The 42 firms which rely on the use of already established principles for their development, and the 26 firms which adopt developments from elsewhere, account together for 221 of the remainder. Only 55 qualified men are employed by the 25 firms in which scientific activity is limited to process control and testing.

Science Graduates

Turning to the graduate in industry, it was found that 99 of the 225 firms employed graduates in one capacity or another, approximately 50 per cent. being employed in actual research and development, the remaining 50 per cent. being spread over other duties such as management, process control, testing, technical sales and so on. Perhaps the most striking feature revealed in this part of the survey was the high proportion of science graduates occupying seats on boards of directors. Out of a total of 684 graduates in the firms visited, no less than 93 (13·6 per cent.) were directors, and these were spread over 70 of the 99 firms found to be employing graduates. The implications of these facts seem to be significant. Scientific knowledge at board level is thought important in a high proportion of those firms employing graduates, and in these firms a certain measure of policy direction is, therefore, in the hands of scientifically trained men.

Directors with graduate qualifications were found to be of two types. There are those who owed their position on the board in the first instance to the fact that they are members of the family owning or managing the firm and who were sent to a university as a preliminary to joining the family business, and those with no family associations who have either

been promoted to the board from some subordinate position in the firm or brought in from outside to give it additional strength.

The majority were found to be in the second category, and a study of the numbers involved will give an idea of the prospects of the science graduate entering industry of attaining this position. It was found that 74 graduates out of a total of 684, or roughly one in nine, had reached board level by his own efforts unassisted by family associations. It was abundantly clear, however, that such advancement was not due solely to his scientific training or knowledge. This may have been of assistance, and possibly even a decisive factor where a choice had to be made between him and an unqualified man of equal merit in other respects, but personality, drive, and the capacity to make decisions, were the qualities which had brought promotion to the scientists and non-scientists alike. It is significant that in no case covered by the survey was it found that a man who had been employed solely on research had been appointed to the board of management of his firm. Any scientist/technologist so promoted had arrived there by way of a position involving day-to-day contacts with the firm's industrial activities. How far inferences can wisely be drawn from that fact, everyone must decide for himself.

Wherever possible the investigators inquired about the departmental duties of the individual graduate in a firm employing a number of such men. From the information so obtained, it has been calculated that there is an almost fifty-fifty distribution of science graduates between research and development work on the one hand, and management, production and other duties on the other. If, however, only those firms are considered where there is a definite research/development department, the science graduates tend to be more concentrated on research or development and the ratio in this case rises to 3 : 2. Little variation in these figures is found if the four industry groups are considered separately, but variations in individual firms of the same group are wide indeed ; particularly is this so in the modern group.

Four examples illustrate this variation and the conditions from which it arises. In the first firm selected for quotation, which employs 750 persons including 31 graduates, production consisted of a large number of high purity products, many for human consumption, so that 25 graduates were employed on testing, standardization and production.

In the second, employing 820 persons including 55 graduates, a most modern plant equipped with the latest instruments and automatic controls called for very highly skilled supervision and maintenance. This had been achieved by employing a relatively large number of graduates for these duties, so that 47 of the 55 graduates employed were on actual production and process control. In this case there was one graduate for every twelve process workers.

The above two examples demonstrate how, in sections of industry where products are standard but techniques intricate, the call is for scientific training and skill in production and in the testing departments.

On the other side of the picture, two other cases illustrate the position where the manufacturing technique is to a very large extent standardized, and the emphasis lies in development of new products or production methods.

One firm employing 750 persons including 75 graduates, had 70 such graduates engaged on research and development, while another, employing 2,000 including 21 graduates, employed 20 of these on research and development. In both these firms the actual production was in the hands of men with diploma qualifications.

The state of things in firms employing quite a large number of graduates is fairly easy to visualize and, as the foregoing examples show, fairly easy to record and describe. The situation where firms employ only one or two graduates is more obscure. In the hope of shedding some light upon it, the investigators considered, separately, 76 firms, each of whom employed between 1 and 5 graduates with a total between them all of 147 graduates.

Some aspects of the picture revealed by this examination of

firms employing very few graduates might have been expected. Thus, only 28 out of the total of 147 are employed by the 13 firms doing original research and development work thereon. The fairly obvious reason for this is that effective research in most cases requires a staff exceeding one or two. Firms, 8 in number, who were doing development work on new information not based on their own research, accounted for 18 of the graduates. Twenty-five of the 76 firms were active in the application of established scientific knowledge and they employed 52 of the graduates. It will be noted that the figures become larger in this category and again the reasons seem to conform to expectations—there is a need for the trained man to bring in and to apply even the well-established scientific principles. Considerable numbers again were employed by firms using graduates for general managerial functions. Of the 76 firms under review, 30 employed graduates for such purposes and between them they had 49 of the total of 147.

Another and most interesting fact which this separate consideration of firms employing very few graduates disclosed was that 58 of these were directors of their firms. Of this number, 40 were equally divided between the modern and the engineering industries and 14 were in the textile industry. Where the number of graduates employed is very small, the chances of their being directors is clearly much higher than is normally the case.

Of the 147 graduates being examined 85 were graduates in science, mostly (49) in the modern industries : 62 held degrees in engineering or technology—20 of these being engaged in the electrical engineering section of the modern industries group—whilst 25 were engaged in other branches of engineering. The inference is that engineering tends in large measure to take men with degrees in engineering and technology, and that the so-called modern industries take mainly those with pure science degrees.

Use of Scientific Personnel in Industry

An attempt was made to assess the degree to which the various firms visited were endeavouring, with adequate staffs, to apply science in a manner which the investigators considered might justifiably be expected. This is obviously an assessment based purely on the personal judgment and experience of the investigating team made in the light of the information obtained by personal contacts with directors and staff. Too much weight, therefore, should not be placed on the results, but these, qualitatively at least, are not without significance.

Four foreign-controlled firms were not included in this assessment, leaving 221 firms for consideration. Fifty-eight of these firms were adjudged to be engaged on operations of a kind which did not call for anything beyond good, daily supervision, of which there are many examples in industry. A clear case is the making of parts or materials for another firm which specified all its requirements. If the process involved is simple, it may well be that no issues involving scientific knowledge arise from one year's end to another. Advocacy of the importance of science to industry should never be carried to the extreme of asserting that high-level science can be of value to every conceivable kind of industrial proposition. On such reasoning as this, and in the light of the facts disclosed to them, the investigators felt that the 58 firms, who between them employed only 2 graduates and 10 diploma-holders, were not open to criticism. There were 12 other firms towards whom they felt similarly. The latter showed a ready disposition to adopt new machines or improved methods, but it was not rational to expect them to engage in research and development on their own account: they employed 2 graduates and 2 diploma-holders. The number of employees in the 70 firms thus considered satisfactory was 13,500.

Next, the investigators classified 73 firms, with 27,000 employees in all, engaged in branches of industry where full efficiency requires both a real understanding and a consistent application of scientific principles already well known and

recognized. Twenty-eight of these firms were regarded as being reasonably staffed from this point of view. They had 33 graduates and 36 diploma-holders between them and employed in all 11,000 persons. Twenty-five firms, with 8,000 employees, had 4 graduates and 6 diploma-holders, and the investigators thought their scientific staff inadequate in relation to their true needs. The remaining 20 firms, with 8,000 employees, had only 5 graduates between them, and the investigators found little attempt to make proper use of the scientific principles which should have been applicable.

Finally, 78 firms, with 100,500 employees, were classified as being engaged in branches of industry which could and should make good use of what science can contribute to efficiency and progress. Fifty-nine, employing 74,000, were regarded by the investigators as well-staffed scientifically : they had 584 graduates and 529 diploma-holders. Thirteen firms, employing 24,500, with 33 graduates and 14 diploma-holders, were thought to have insufficient scientific personnel, whilst in 6 firms there seemed no real policy in this respect, they having but 6 graduates and 1 diploma-holder between them.

These *ad hoc* judgments by three investigators are offered in this Report because it seemed to the Council of importance that such opinions should be expressed and recorded. But the reader is again reminded of the reserve which should always be exercised in formulating dogmatic conclusions on the strength of one man's impressions, even when these are checked with two colleagues. In so far as these assessments approximate to the truth, the picture they reveal is interesting. If the cross-section is representative of the whole, one-third of industry does not really require much from science : another third requires mainly competent application of established principles, and only the final third really needs the aid and stimulus which science alone can give. In the last and most important section, the scientifically qualified staff is satisfactory in five-sixths of the firms : in the middle section it is adequate only in two-fifths.

Some of the firms covered by the foregoing assessments undoubtedly felt a need for stronger staffs. Smaller firms in many cases remarked on the custom of the very large ones in sending representatives to the various universities regularly each year so as to contact students before the final examinations and engage the most promising. The small firms, having only an occasional vacancy for a graduate, could not establish themselves so well in university circles and the claim was made that they suffered in consequence. The graduate naturally will seek the best conditions of employment he can get, and unless the smaller firms are prepared to offer conditions of service and opportunities comparable with those obtaining in the larger ones, it seems that their complaints are not well founded. If they do offer adequate terms, it seems likely that some of the best of the graduates will prefer the small firm to the large.

The universities are being asked to supply many more graduates in scientific subjects than are available, and it is evident, therefore, that industry generally is suffering from a shortage of scientific staff. Small firms as well as large must face the realities of this situation, and the investigators feel the small firms should have definite attractions for a certain type of graduate if they would tackle their recruitment problems with a consistent determination to overcome them.

A question commonly asked is whether outstanding research and development by an industrial firm is a consequence of the employment of scientists or technologists by the firm, or whether the drive for such work more usually comes first from the directors who then gather a staff adequate to implement their plans. Ten firms, which had undertaken research for the first time in the last ten years, were specially considered by the investigators in order to attempt to shed some light on this most important point. It was possible in 8 cases to state quite definitely that the development work was initiated by men who had been engaged primarily for managerial or

works control purposes and were all men with industrial experience. Half of these firms do not have a science graduate on the board of directors and the research or development work now being undertaken is clearly an extension by the staff of their duties as originally visualized by the directorate. In the other 4 cases, the founding of a research and development section can definitely be attributed to the influence of graduate directors in seeking to raise efficiency.

The presence of scientists on the staff obviously does not of itself lead to successful research or development work being undertaken. Thirty-one firms amongst those visited employ graduates without making any effort to carry out advanced work. The average number of graduates employed by these firms is rather less than 2, of whom rather less than half are directors. All are employed on managerial, works control or testing duties.

The Graduate's Influence on Contacts with Outside Sources of Information

A field in which the presence of graduates in a firm has considerable importance is that of consultations with the universities. One firm in three of those employing graduates makes regular contacts with a university as compared with only 1 in 20 of the firms with no graduate employees.

In view of the influence of graduates on the frequency of consultations with the universities, a similar analysis was made for consultations with the research associations. No corresponding effect was observed, the size of the firm proving to be the dominating factor. This is no doubt to be expected in view of the wide range of assistance, from highly scientific to technological and technical, which the research associations can provide.

The presence of a science graduate on its staff might lead one to expect a firm to have a somewhat greater interest in the possibilities of sponsored research, and this has in fact been found to be the case. Practically all of the firms which showed

an interest in the possibilities of sponsored research do employ science graduates in one capacity or another.

Before leaving the subject of the employment of graduates in industry, it seems desirable to draw attention to one fact which made a deep impression on the investigators. In all cases where graduates were employed, it was found that they were regarded with respect, and that appreciation was shown of their value to the firm employing them. A few instances were encountered in which a firm had at one time engaged a graduate and discovered ultimately that he either did not fit in with the organization as it existed, or seemed unable to pull his weight. It is usually found on further questioning that the graduate was a raw recruit, and that failure on his part to fit in was largely due to lack of guidance as to what he should do and how he should set about it.

Where a young graduate is recruited by a firm already staffed with one or more qualified men, he has the opportunity of learning these things from his graduate seniors and the chances of his not settling down are small. Where, however, he enters an establishment in which he is the only graduate, the case is very different, and being new to industry he may find his surroundings strange and alien to those to which he has been accustomed. If, further, he is the first graduate to be engaged by the firm, not only will he be ignorant of what he should do, but it is equally possible that the management itself is just as hazy as to what should be expected of him. Several firms employing only one or two graduates emphasized the fact that it is essential for a graduate on entering industry for the first time to have such guidance from an experienced fellow-graduate. This problem might well be solved with the help of older men engaged in other firms, though if a firm really requires and expects industrial experience they must pay the rate for the job and recruit from the ranks of those who have already spent some time in industry.

It may be of some interest if the views are given of three firms concerning the period of training that is required before a graduate entering industry directly from the university starts

to pull his weight or becomes adequate for the work for which he was really engaged.

The first case is that of a large firm with a well-organized research and development section which undertakes true fundamental research as well as applied research and development, and where there is a full staff of qualified chemists, engineers and physicists. A new recruit is allocated to a certain section leader in the research or development department who is usually in charge of three or four assistants. With careful nursing and encouragement from his chief and his colleagues, he finds his niche and begins to do useful work in two to three months. The policy in this firm is to try to select research-minded individuals who are not primarily out to seek monetary gain from patents, or bonuses for any discoveries they may make. The firm tries to ensure that all individuals in these sections are free from financial worry so that they can give of their best without undue concern for the future of themselves and their families. The research manager said he had always been well satisfied with the recruits he had engaged through the university appointments boards.

Another firm has little need for graduates for real research as this is all done by the research team of a parent firm. Their need is for men who can develop the results of such research and follow it through the pilot plant stage until it has been successfully adopted in works' practice. For this reason they prefer to obtain graduates in chemistry, engineering or physics, who have had some industrial experience, rather than those straight from the universities. In their experience, a graduate new to industry needs about three years' works' experience before his scientific training can be usefully applied, and they prefer this to be completed before appointment.

The third firm was looking for an engineering graduate of first-class ability but without any industrial experience, who could be trained in the firm's business with a view to promotion to board level in due course. They wanted a man willing to go through each department and work with his hands until he knew the whole production process inside out, and not until

then to expect managerial status. The managing director estimated that this would take from seven to ten years and said that so far the university appointments boards to whom he had applied had been unable to satisfy his needs.

These divergent points of view, of three firms seriously interested in the employment of graduates, emphasize how widely the period of industrial training can vary with the type of position to be filled. Whereas a graduate entering a research department finds his feet fairly soon, no doubt because he is doing work of a kind with which his university training has familiarized him, another, who is destined for a post outside the laboratory, may not be fully qualified to occupy it for several years.

Diploma-Holders

Leaving the graduates and turning to holders of diplomas, it should be recorded that the investigators found that this class of technologists again stands very high in the esteem of industrialists. For the most part they were to be found in firms which also had graduates on the staff, but in some cases they were the only qualified personnel employed. Some managements preferred diploma-holders to graduates on the grounds that their training and experience were more practical. This applied particularly to small and medium-sized firms which did not undertake highly scientific research and development work, but were content with just one or two men with a scientific background for the normal running of the factory or works. Such firms obviously were of the opinion that holders of diplomas, having usually spent several years in industry before obtaining their qualifications, had a better opportunity than the normal graduate of combining their scientific studies and their practical experience. This view is recorded as one which was not infrequently encountered without necessarily implying agreement with it.

It was more usual to find diploma-holders employed in management and process control than in research and develop-

ment, but there were cases, particularly in the electrical engineering industry, where they were well able to hold their own in the research and development laboratories. Where a firm had both graduates and diploma-holders on its staff, the former were normally to be found undertaking research and development whilst the latter were concentrated rather more on the production side.

From the evidence collected, it appears that the diploma-holder has a smaller chance of promotion to the board of directors than his graduate colleague. Thirty-five diploma-holders, representing 5·7 per cent., have reached this level compared with 13·6 per cent. in the case of graduates.

Holders of diplomas were mainly to be found in the mechanical engineering industry, which accounted for 295 out of the total of 613, but the chemical and electrical engineering industries were also well represented. These three industries together employed nearly 85 per cent. of the whole number. Large firms with over 500 personnel absorbed 87 per cent. of the total, and it was fairly common to find as many as 10 or more diploma-holders in one such firm ; all of these, however, without exception, employed graduates as well.

It is of interest to consider briefly some 20 firms who employ diploma-holders but no graduates, in which group small firms in the general engineering and building industries predominate. Seventeen of the firms had only one or two diploma-holders on their staffs, and the position held by such men was of a supervisory nature either on the board or as chief engineer. None of these 20 firms had a research department of its own, but two benefited from the research departments of associates, and 5 had their own small development sections in which experimental work was conducted under the guidance of a diploma-holder. The majority, however, had no development facilities of an organized nature, and any advances in technique or in the application of scientific knowledge consisted of minor innovations or in the adoption of ideas which had already been applied successfully elsewhere.

Two exceptions were found—in the first case, a firm in a

specialized section of the chemical industry had a managing director of vision and imagination who himself directed a small and efficient development section. This development section had an Associate of the Royal Institute of Chemistry and a few laboratory assistants of National or Higher National Certificate standard. All these men were well versed in the practical application of chemistry to their own particular field and fully capable of carrying out experimental investigations on the instructions of the managing director. The second firm, in the electrical engineering industry, had a total of 8 Members or Associate Members of the Institution of Electrical Engineers, including 2 on the board of directors, and possessed an efficient development department capable of doing everything necessary to keep the firm up to date with the latest improvements and of designing new equipment to meet the specific needs of individual customers.

In the textile industry there is at present a considerable drive to raise technological standards. Though the system of training now in force is possibly not such as can be considered equivalent to that of the accepted diplomas in science and engineering, there is little room for doubt that it is improving very rapidly and has already proved of considerable value to the industry.

Firms with no Qualified Staff

What of the 107 firms which were visited and found to have no qualified men of degree or diploma standard? In many cases it seemed to the management that, for the nature of the firm's business, there was no obvious need for a man of that calibre. Examples of the trades predominating amongst these 107 firms are the woodworking industry, small general engineering shops, and works fabricating standard articles from paper and board where a graduate or diploma-holder might be regarded as unnecessary. Such a man might, indeed, feel thwarted in that the conditions under which he worked lacked scope for the exercise of the capabilities derived from his train-

ing. The same view was apparently held by managements in certain sections of the textile industry, particularly those handling natural fibres where practical knowledge and experience count for so much. In such cases it was often the opinion of the directors that, provided there was someone on the staff with sufficient scientific knowledge and practical experience to understand, and appreciate the significance of, the reports of the appropriate research association, there was little need for the presence of graduates or diploma-holders.

Four firms without qualified staff had definite development departments of their own, but the work they undertook was all based on principles already well known to the industry and was distinctly limited in scope. They were, however, under the direction of men of drive and experience, and the investigators thought they served fairly adequately the purpose for which they were intended. There is little doubt, however, in the minds of the investigators that the introduction of a qualified man in such instances would greatly enhance the value of the departments concerned.

Apart from these 4 firms, a further 26 said that a certain amount of development took place in the improvement in technique. Although a qualified man might possibly be of value in extending the range of these improvements, the managements appeared to be quite satisfied that their existing staff was competent to do all that was required. The remaining 77 firms were of the " bread-and-butter " variety and undertook no development work of any kind, being apparently content merely to keep the wheels turning. A few of them said that they kept an eye on the efficiency of their process, but the investigators felt this was done in a rather uncertain fashion. If the firms without qualified staff are considered as a whole, the impression was gained that, no matter what their own managements might feel, the services of someone capable of undertaking a really skilled supervision of processing efficiency would in many cases have been of real value.

From what they were told, the investigators conclude that 32 of the 107 firms would obtain real and lasting benefit from

the employment of a qualified man of degree or diploma status.

In addition to the two classes of trained men already discussed, there is another type which calls for brief comment. These are men trained to National or Higher National Certificate or some corresponding standard. These are undoubtedly an increasingly valuable force in industry, well capable of quality control, testing and work of similar nature. It did not prove possible to determine how many members of the firms visited held qualifications of this nature, but, so far as could be ascertained, workers with such qualifications were commonly employed as laboratory and drawing office assistants and had reasonable opportunities for promotion.

Draughtsmen

Before concluding this chapter, there is one other group of men with special technical qualifications to which reference should be made. The drawing office staff, although they may not necessarily hold degrees or diplomas, play an important rôle in the development programmes of many firms, particularly in those connected with engineering. It seems appropriate, therefore, to include some account of the position regarding drawing office staff as revealed by the survey.

Many of the firms who were visited reported that there was a general shortage of good draughtsmen—particularly design draughtsmen as distinct from those engaged in normal routine drawing office work—and no less than 23 stated that as a result of this shortage their firm's developments were being hampered. It was stated that not only were good draughtsmen difficult to obtain, but that they were in some cases equally hard to retain. Competition had reached such a pitch that draughtsmen were constantly leaving one firm and going to another which offered higher salaries. There seems to be little comment to make on this state of affairs which can contribute to its solution; it has been generally appreciated for some time that this shortage does exist and the information obtained during the

course of the survey does little more than confirm it. The drawing office is used by many firms as a training ground for their plant and production engineers ; there is, therefore, a constant drain on the drawing office even in those establishments which may otherwise be adequately staffed. It was, in fact, suggested to the investigators that the shortage of draughtsmen is no new condition, but that it has always prevailed, and will not be rectified until more young men can be influenced to enter industry through this channel. Another factor which was said to have aggravated the position was the present rearmament programme, which necessitated the use of large numbers of draughtsmen both in government factories and in firms undertaking contract work for various Ministries.

The comments of an American director of one of the firms visited regarding the duties of a draughtsman in this country as compared with his counterpart in America are not without interest. He said that in America the draughtsman was in far more intimate contact with the practical side of a works or factory than in Britain, and that it was quite usual for a draughtsman who had designed a plant or piece of equipment to take a hand in its actual production, erection and operation. His own experience had been that the draughtsman in this country was inclined to stick to his board too much and not get out on the plant to see how the projects he had helped to develop in the drawing office worked in practice. This is an expression of opinion made to the investigators by one particular director, and may or may not be generally true, but it seems important to record it as the impression of one with a wide knowledge and experience of industry in another country as well as our own.

Summary

Summing up, it can be said that just over half the firms visited have at least one scientist or technologist. The majority of graduates are found to be engaged in research and

development work, either directly or in its application, and holders of diplomas are usually occupied with supervision and operation of works' plant and processes. There seems to be room for improvement in the extent to which both classes are used to undertake regular or spot tests to determine the efficiencies not only of the main process or operation, but also of ancillary plant and equipment. It is believed that it is in this latter direction that scientists could be of much immediate service to some of those firms which at present do not include graduates or diploma-holders on their staffs.

The purely scientific training of the graduate or diploma-holder does not of itself mean an ability to visualize or carry out efficiency tests, and some training is necessary in the industry itself. A few years' experience of high-quality industrial control will engender in the scientist a sense of the necessity of knowing everything possible regarding the efficiency of the plant or processes under his control. His scientific training should then enable him to plan and conduct such tests in any industry, no matter how different from that in which he has had his original practical training.

The survey has also shown that scientists and technologists are well represented on the boards of directors, and that there is ample opportunity for such men, particularly those of graduate status, to gain promotion to this level. The mere fact that they have scientific training is, however, insufficient by itself; they must also have personality, experience and drive, and not restrict their activities and interests into too narrow a channel.

There is a strong tendency for those firms in the categories " Developing ideas from research " and " Development from established principles " to be those with graduates on the staff. Where there are graduates on the staff, the presence of graduates on the board does not seem necessarily to affect either policy or achievement. On the other hand, where there are no graduates on the staff, a distinctly higher proportion of the firms with graduates on the board seem to achieve more.

That the industries classified as " Modern " in this survey

have much more scope for research and development than do the other groupings, is confirmed by the fact that nearly two-thirds of the firms having four graduates or more are to be found in the modern industries.

Whether research or development work in industry stems from the employment of scientifically trained men or from an enlightened management is perhaps not quite clear from the information gathered. That such work cannot be carried out without the qualified man is, of course, obvious, but that such personnel can be employed for a long period without any research or development being undertaken is equally clear. It would appear then that both suitably trained men and managerial pressure are usually required if such work is to be carried out both successfully and efficiently.

Where the higher management, deciding that a scientifically trained man is necessary for progress and well-being, selects someone with experience in a firm or industry where research and development is a normal function, and permits the new employee to plan his own work, there will normally be a certain amount of research carried out. If, however, the trained man engaged is lacking in industrial experience, or if his day is completely filled with testing and routine duties, little more than routine results can be expected.

Tables 1–12.

CHAPTER III

INTERNAL RESEARCH AND DEVELOPMENT BY INDUSTRY

As has already been mentioned, the investigators found that such diverse ideas were held in industry as to what constituted research—ranging from true fundamental investigation down to the mere introduction of minor innovations and gadgets—that only by devising a definition of their own, and using this as a yardstick, could any clear picture of the extent to which research is undertaken by firms in the region be provided. It must at once be acknowledged that the definition adopted is open to certain criticisms, but it does at least provide some means of distinguishing between research and development and permits of definite comparisons between different firms.

For the purpose of this Report, therefore, industrial research is taken to cover the investigation, either by laboratory techniques or by systematic observation on working plant, of the properties and reactions of raw materials and of intermediate and final products, together with the investigation of any other characteristic, chemical, physical or mechanical, which may affect their manufacture, manipulation or utilization. The object of such research is to assist in improving existing products, in evolving new ones, or in making use of new raw materials or processes. It may include the adoption of a well-established principle, provided that it is new to the particular industry and entails a certain amount of laboratory or test-room experiment before it can be fully developed and applied. It does not include, however, the adoption of a well-known practice, already in a fully developed stage elsewhere, which merely calls for some slight variation in technique before becoming applicable in a new environment, or to a new function—such innovation being classed as development.

Thirty firms among those visited, or 13 per cent. of the whole, were found to be undertaking research conforming to the definition set out in the previous paragraph ; whilst a further 13 had research facilities available at an associated firm or establishment. They were for the most part confined to those in the larger size-groups and to the chemical, mechanical and electrical engineering industries, and each of them had at least one graduate either on the board of directors or the staff. In many cases there were sufficient graduates on the staff to permit small teams of three or four men to be employed on specific projects, but even in smaller firms, with only one or two graduates, there were several experienced laboratory assistants to work under the direction of a graduate. In each research section there was usually one man who could be regarded as the head or leader, and while he was often given a fairly free hand regarding the work being done, it was nearly always laid down that this must be on subjects closely allied to the firm's interest, and that priority must be given to those problems which the board of directors considered to be the most important. The following of side-lines which might come to light during an investigation was not generally encouraged. It is clear that the research scientist in industry does not, as a rule, enjoy the freedom in choice of subject, or the wide scope permitted to his academic counterparts.

It is noteworthy that the one example encountered in which a research man was given authority to follow such a side-line resulted in a really striking discovery which has proved of substantial value to a section of industry outside the firm's own activities. The firm itself has, of course, benefited by the discovery, as it has been taken up by others under normal licence and patent procedure, but it would be but fair to acknowledge that only a firm with a large research staff could afford to release a man from his ordinary duties and permit him to follow a line of research outside the company's direct concern.

Not all firms had their research organizations at the actual establishment visited and it was quite usual to find in the

cases of a multiple firm or combine with several establishments that there was a central research organization which catered for all the associated works or factories. Each establishment had, however, its own development department which applied the results of such research to its own needs and, of course, had the benefit of guidance from the central research department throughout. The investigators were assured that this system ensured that there was no duplication of research in the company, whilst, at the same time, permitting each establishment to exercise considerable freedom in the matter of subsequent development. Attention must again be drawn to the fact that none of the very large firms with many establishments dispersed throughout the whole country, and interested in diverse fields of the same general classification, is included in this survey.

It was found by the investigators that industry as a whole is willing to discuss its development work freely, but exhibits some reserve when the talk turns in a detailed manner to the scope and nature of their private research work, a reserve which the investigators themselves felt was entirely reasonable. In the competitive field of industry, research is one of the most important means by which a firm strives to forge ahead of others, and the veil of secrecy is not lifted until the fruits of that research are ready for presentation, or until it is felt that such a lead has been established over competitors that the advantage gained will not be jeopardized. None the less, the investigators were accorded the opportunity of discussing the general trend of research at a number of establishments, and it became evident that, except in a few isolated cases, very little in the way of long-term fundamental research is being done in industry itself, such work being normally considered by the industrialist as outside his province.

In only 6 of the firms was there any sign that a thorough study was being made of the basic, underlying principles behind observed phenomena. In all other cases the work was applied research, in which the object was the production of a new or better product by a novel or improved method.

The position may be somewhat different where the very large, nation-wide firms in the modern industries are involved. For all other kinds of industrial concern, at any rate as far as the work of this survey reveals the position, the function of a research department is to be a service department to the board of directors and management in providing knowledge and information expected to be of direct assistance and guidance to the production departments.

Firms with research departments of their own, or which are in association with such firms, were found to be concentrated in the larger size-groups and 29 of the 43 had over 500 employees. The modern industry group was most frequently represented with 20 out of the 43 firms, whilst the engineering group had 10, the miscellaneous group 9, and the textiles group 4. The low number of textile firms is no doubt due in part to the proximity of the British Cotton Industry Research Association (the Shirley Institute), and is an indirect commendation of the work done by that organization. It is

Firms with Research Facilities

Industry Grouping	No. of firms in Group	No. of firms with research facilities	Percentage of firms visited which have facilities for research
Modern	58	20	35
Engineering	68	10	15
Textile	51	4	8
Miscellaneous	48	9	18
Total	225	43	19
Size Grouping			
50–99	51	3	6
100–249	80	7	9
250–499	29	4	14
500–999	40	14	35
1,000 and over	25	15	60
Total	225	43	19

also partly due to the fact that the textile industry is, to a large extent, a purely processing industry in which the fundamental nature of the raw material remains unaltered by the operation.

The actual percentages of firms in each industry group, and in each size-group, which had research facilities available to them are summarized in the table on the previous page.

Research in Multi-Establishment Firms

Earlier in this Report attention has been directed to the difference drawn between an establishment and a firm, and it is of interest to consider the set-up of research/development in some of the multi-establishment firms visited.

First there is the position of those firms in which the combination is a somewhat loose association in so far as the separate units have, in a large measure, retained their individuality. Five firms of this type were visited and it was noted that in 3 cases each of the member establishments supports a considerable research/development department of its own, while being kept well informed of all work being carried out by the other members of the group. One of the remaining 2 is itself the result of combining the research departments of a number of firms in the same field of manufacture, and has really become a private research association. In this case, each member firm still supports its own experimental and development department. The other firm supports a considerable experimental and development department and carries out a small amount of *ad hoc* research, though depending chiefly on the central research organization of the combine. In all 5 cases there is a carefully planned system for the dissemination of scientific information throughout the whole association.

In 3 firms where the combination is close and integration is more complete, there is one central research organization serving all establishments. All fundamental and long-term

work is done at the centre, though in two cases the individual establishment has a laboratory and carries out developments most of which are of particular interest to itself. Collaboration between the works' laboratories and the central research organization is very close, and in these two cases interchange of staff is a regular occurrence. In the remaining firm, all research/development work is carried out by the central organization, and any other laboratories are equipped only for the normal works' tests and carry no qualified staffs. When any work is required by a particular factory, the research department delegates staff to carry it out in conjunction with local management. It was felt that the dissemination of knowledge throughout this firm was well planned and effective, though perhaps it would not have conveyed a great deal to the individual establishments had the central staff not been available to assist.

Four subsidiary establishments of foreign firms are included in the survey and it was noted that all were assisted by a very large research and development department at the firm's headquarters. In addition, one firm had a strong, well-staffed research and development department at the British establishment, a second had a small section devoted to such work, while the remaining two depended on headquarters for all save purely technical information.

Five more establishments covered were branches of firms with headquarters outside the area concerned, but still within Great Britain. One of these is the complete research and development department servicing a number of establishments spread throughout the country and carries all work through to the pilot plant stage.

The remaining 4 have the services of a research and development department at headquarters, but only one conducts any research at the local establishment ; one has a development section on its local site, one carries out a small amount of development work and the fourth confines its activities to standard production.

Other multi-establishment firms were included in the visits

made, but only one of these calls for particular comment under this heading. This is a somewhat loose collection of firms spread fairly widely throughout the country, and while all are in the engineering industry their products vary considerably in type. So far as could be ascertained, none of the allied establishments is in a position to provide other than purely technical information, and the research carried out at this particular establishment is confined solely to its own problems. The work is not great in volume, being an extension, by an individual graduate, of his testing and production duties.

It is not proposed to comment on the staffing of these research departments ; this has already been discussed in the previous chapter, but it is interesting to note that out of the 43 firms concerned no fewer than 26 had directors of degree standard.

The Cost of Research

One of the questions a firm considering the formation of a research department must ask itself is : " What is it going to cost, and what will the firm derive in material benefit ? "

There have been many attempts to answer this question, both here and abroad, but so far as is known none has proved wholly satisfactory. Although it is quite possible to estimate the capital cost of establishing a modest research section and to budget for its annual upkeep, it has generally been found impossible to produce a profit and loss account to show to what extent a research department is paying its way. So many of the advantages of such a department are so intangible that it is, perhaps, not surprising that this survey has not brought to light any new ideas as to how such a balance can be struck, nor how the value of such a department can be assessed. There is nothing which can be pointed to as an infallible indication that a firm needs a research department, or that it will be profitable to found one. Perhaps not unexpectedly, wherever a research department was found to exist, it was thought by

the board and management to be a most important aspect of the firm's activities, and the best means of keeping abreast of progress. The decision to institute research can only be taken after mature consideration, but, even so, it will still be largely a matter of faith, and a belief that the scientific method has advantages over those of trial and error. It would appear that industry in the Greater Manchester Area is becoming increasingly appreciative of the value of undertaking research work on its own account. Out of the 30 research laboratories possessed by establishments visited, 10 have been founded within the past ten years.

It did not prove possible to assemble reliable figures showing what amount, either as a total or as a percentage of the firm's turnover, was allocated to research/development work. In the firms with small graduate staffs in which the research/development was a part-time activity, it was obvious that no effort was normally made to determine costs.

Development

The nature of the development work undertaken by those firms with research facilities is based, in the majority of cases, on the results of such research : this is true for 38 of the 43 firms. The remaining 5, which have the resources of an external research department and a development department of their own, do not use the results of such research themselves, but have the advantage of the existence of an associated research department to help them if need be in their more modest requirements. Two firms included in this group of 5 were found to be undertaking no energetic development work ; they are purely " bread and butter " establishments of fairly large combines turning out standard products and are concerned with keeping an eye on the market for those products.

Each firm with a research department of its own had some form of development organization to carry the results of this research to full-scale production. Sometimes the two were

combined, and a research team would continue its work through the development and pilot plant stage until it was finally incorporated in the normal production scheme. In other cases, the laboratory or test-room results of research would be handed over to a development team and the research department would then act solely in an advisory capacity. Whichever plan was adopted, the new process or product was supervised in the early stages of its adoption by the development team until the production side was satisfied that it was a working proposition and could be taken over by them as such. It was unusual to find that external assistance was called in during the actual research stage of a project. No doubt a desire to maintain secrecy was one reason for this, but it is significant that when outside aid was solicited, it was to the universities that the firms looked more frequently than to research associations or consultants.

Whereas research is confined to a comparatively small section of industry, development of one kind or another is much more common. Indeed, there were few firms visited which did not have some sort of investigation, which they termed development, going on in their works or factories in order to improve the quality of their products, or to reduce the cost of production. It follows from this that the interpretation of the term " development " must vary widely from firm to firm, and were no effort made to distinguish between these different interpretations, conclusions as to the extent to which development is undertaken by the firm surveyed might be misleading.

It would clearly be wrong to give equal recognition and status to a firm undertaking major development projects involving the use of pilot plant, full-sized mock-ups or prototypes and one where the development consisted solely in the redeployment of machines or personnel. Each is undertaking development of a kind, and the kind chosen may be best suited to its needs, but the extent to which scientific knowledge is required in the two cases is vastly different. It has seemed rational, therefore, to sub-divide development into four groups

based primarily on the degree of scientific or technological knowledge required. In the highest category come those firms undertaking developments based on the results of research carried out in their own works or elsewhere. These have already been covered in the discussion of research departments. Next come those which take some well-established principle and then adapt it to their own needs. The third category comprises those firms which readily adopt processes and practices already fully developed elsewhere, and finally there are those who are content with minor innovations and the introduction of time- and labour-saving practices or devices. Lastly, a considerable number of firms showed no vigorous activity in any of these classes. In some of the comments made in the previous chapter regarding the employment of scientists, this classification of four types of development has already been used and has also been employed in several tables of statistics appearing in Appendix 1.

Facilities for development were more in evidence than those for research, and some 40 per cent. of the establishments under consideration were found to be equipped with departments responsible for the implementation of development policy. Their functions varied widely, both according to the nature of the industry and the niche the firm filled in the general pattern of that industry. They all had, however, for their object the introduction into works' practice of some feature which would strengthen the efforts of the firm to keep ahead, or at least abreast, of its rivals, and to hold its own in a competitive market.

In firms with research departments of their own, the course to be followed was fairly clearly defined. The results of research work on the laboratory or test-room scale needed to be translated into full-scale production, and it was the function of the development section to consider the best means of achieving this and then to carry it out in practice. A new product had been prepared in the laboratory, or a new process devised, which had distinct advantages compared with the methods of production employed. How could these be used

by the firm to the best advantage? What difficulties would arise in full-scale production which might have been overlooked in the research stages? These were the types of problem which the typical development department which drew its ideas direct from research results was called upon to solve.

Considering first those firms which have the benefit of a separate research department, it was found that 43 came into this category. Thirty of these had research departments on the premises actually visited, and in all these cases there was an associated development department which translated the results into practice. A further 13 establishments relied on the research departments of parent or associated firms, and of these 10 had their own development departments which were used to develop the results of research coming to them from these external sources. The remaining 3 establishments were without development sections of their own, the parent or associated firm being responsible not only for the research, but also for the introduction of its results into normal operation.

Developments which were not based directly on the results of new research were somewhat different in character. The investigators found that in such cases, although a certain amount of experimentation might be required to confirm that the new project was a practical proposition, the depth of scientific knowledge required was, as a rule, somewhat less than that in those cases where the development arose as a direct result of research. It was found, therefore, that the functions of development departments varied considerably, according to the nature of the work which they were expected to perform. In addition to the 40 firms having departments whose function is both the derivation and the application of new knowledge, 49 firms have a definite department to study, plan and carry out developments originating from other sources.

These 49 firms with no research facilities but with their own development sections occur to a greater extent in the modern industry group than in any of the others, but the size factor also proves of considerable significance. From the

smallest size-group (8 per cent.), there is an increase up to the 250–499 group—which shows the highest percentage (38 per cent.)—and then a falling off. This is not altogether unexpected, as such firms, while being large enough to undertake development work, might hesitate to found a research department with its high capital cost and upkeep charges.

FIRMS WITH DEVELOPMENT DEPARTMENTS BUT NO RESEARCH FACILITIES

Industry Grouping	No. of firms in Group	No. of firms with Development Departments	Percentage of firms visited which have Development Departments
Modern	58	22	38
Engineering	68	13	19
Textile	51	8	16
Miscellaneous	48	6	13
Total	225	49	22
Size Grouping			
50–99	51	4	8
100–249	80	17	21
250–499	29	11	38
500–999	40	11	28
1,000 and over	25	6	24
Total	225	49	22

The staffing of these departments has been discussed elsewhere, but here again it may be noted that 22 out of the 49 firms have a director of degree standard which, although not so high a proportion as in the case of research departments, seems worthy of mention.

Of the 133 remaining firms with neither research nor development department, there is little to be said. Only 16 firms (27 per cent.) of the modern industry group come into this class and they are small firms in which what development is done is a part-time function of one of the executive staff. The remaining industry groups are much more strongly represented and the figures show that the percentage of firms

in each group without either research or development department is 66 for engineering, 77 for the textile, and 69 for the miscellaneous group. In all four industry groups it is the smaller firms which predominate, but even so there are 4 firms with over 1,000 employees. These 4 firms are made up of 3 textile firms and 1 engaged in building and general contracting work. Two of the textile firms are engaged solely in spinning, whilst the third, which is vertical, although having no definite research or development department, has a development panel which considers new lines of production based on market research.

Further examination of the different types of development undertaken by various companies reveals that firms in the modern industry group base their development mainly on ideas gained from researches and established principles, whilst firms in the engineering group undertake developments based, to a large degree, on established principles or innovations. This is only to be expected, since the modern industries, by their very nature, are most closely linked with activities deriving from new knowledge, whilst in the engineering industry this does not obtain to the same extent. The textile industry, on the other hand, relies most on the adoption of ideas developed elsewhere, which in this instance usually means either the Shirley Institute or the manufacturers of textile machinery.

When firms are classified according to the scientific qualifications of their staff, it is found that the effects of both size of firm and of industrial group disappear—approximately 50 per cent. of the firms with graduate staff being classified as " Developing ideas from research " regardless of size, industrial group or scientifically trained members of their board, and 25 per cent. as " Development from established principles."

Firms were invited to state the sources from which they had derived help in their development work, and the answers, of considerable interest, are listed below :

Source of help mentioned by firms consulted	Number of firms mentioning it
Suppliers	91
Research Associations	45
Customers	42
Universities, etc.	41
Department of Scientific and Industrial Research, etc.	39
Consultants	33
Trade Associations	26
Friendly Firms	17
Foreign Associates	10
Others not classified	21
None mentioned	45

Tables 13–23.

CHAPTER IV

THE RESEARCH ASSOCIATIONS

An important aspect of the survey is the light which it has thrown on the relationships existing between the firms visited by the investigators and the co-operative research associations maintained jointly by firms engaged in particular industries and the Department of Scientific and Industrial Research. In October 1952 there were 42 such associations, of 28 of which one or more of the firms visited were members.

There are still, however, a number of branches of industry whose main products are not directly covered by the work of any of the existing research associations connected with the Department of Scientific and Industrial Research. This, for example, applies in the glass industry, in certain sections of the chemical industry, in brewing and in some special branches of engineering; and only three-quarters of the firms interviewed were engaged in industries for which there exists a research association doing scientific work directly connected with their activities. No less than 86 per cent. of the firms eligible for membership were in fact members of the appropriate research association. Of those eligible by reason of the nature of their products who were not members, a few were ruled out by reason of their being associated with, or controlled by, foreign companies. This is explained by the fact that the research associations supported by the D.S.I.R. normally confine their membership to British firms. On the evidence gathered, therefore, it is safe to say that where there is a research association devoting itself to a particular branch of industry, it is in most cases supported by all but a minority of those eligible to join.

Research associations of the kind now under consideration are not necessarily the only places where scientific research may be proceeding which is, or could be, of value to the firms

included in this investigation. There are several research institutions supported entirely by the State (without industrial membership) for which the Department of Scientific and Industrial Research is alone responsible, the National Physical Laboratory and the Fuel Research Station being the two examples most frequently mentioned. In a later chapter, dealing with the varied sources of scientific information and knowledge of which industry can avail itself, some further reference to these governmental institutions is made. There are also certain private laboratories where research is done for others than the owners, including one or two which undertake specified or sponsored research for fees, and a few others which have been set up by the joint initiative, and at the joint expense, of a group of firms having some common objective in view. It is well to bear in mind, therefore, that what is said in this chapter or elsewhere about the research associations is intended to refer specifically to industrial co-operative research supported by the D.S.I.R., and does not necessarily cover the whole field of available research activity outside the laboratories of individual firms which work only for their own proprietors.

It is unnecessary here to give an account of the origins of the research association movement, or of its present-day scope. Dr. D. W. Hill's book *Co-operative Research in Industry* and Professor R. S. Edwards' *Co-operative Industrial Research* may be consulted by those who wish to know more about the movement and its accomplishments. At the end of this chapter will be found a list of the research associations covering industries with which one or more of the firms visited were concerned, among which the British Cotton Industry Research Association, with its laboratories at the Shirley Institute, figures largely. This is to be expected, having regard to the great importance of the cotton industry in the area of the investigation, and of the location of the Institute in Manchester. The investigators did not attempt to visit all the research associations, nor to secure their point of view, since this inquiry had for its main purpose the disclosure of the facts from the angle

of industrial firms. Visits were, however, paid to the Shirley Institute, to the British Rayon Research Association, and to the laboratory of the British Hat and Allied Feltmakers' Association. Although these covered but a small part of the field of the research associations concerned, they were useful to the investigators as a reminder that there was another side to the picture presented by their conversations with industrial concerns.

Membership and Use of Research Associations

Out of the total of 225 interviewed, 151 firms supported the research association movement. The majority of these were content with membership of the one association most closely connected with their own business, but several cases were found where firms belonged to more than one. Some textile firms making goods from more than one fibre found it desirable to join two or more of the research associations covering their individual raw materials, cotton, wool or rayon, while others thought it also desirable to subscribe to organizations concerned with one or more of their subsidiary or ancillary activities. It was found, for example, that certain textile machinery manufacturers belonged to the cotton or wool research association as being those of interest to their main customers, whilst some chemical firms were members of one or more of the textile associations, the Launderers' Research Association, or the Leather Research Association. Two firms, completely outside the field of electrical engineering, had joined the association serving that industry in order to keep in touch with developments which might help them in their production methods, either directly, or through new techniques in such fields as electronic control and instrumentation. The sphere of influence of a research association may thus extend considerably beyond the boundaries of that industry for which it was originally founded. A firm which at first sight concludes that no research association can be of use to it, because none exists to cover its main product, may well find on closer examina-

tion that there are others which have something useful to offer.

Fourteen of the firms visited considered it worth while to belong to three or more research associations. One large vertical textile firm is a member of six—cotton, wool, rayon, hosiery, laundry and electrical ; and one in the chemical field belonged to four—cotton, wool, paint and rubber. Those firms which are members of three or more research associations were mostly fairly large in size, 12 out of the 14 employing over 500 persons. The exception to this generalization was one in a specialized section of the chemical industry which had fewer than 100 employees. All the 14 firms are well staffed with academically or technologically trained men, and 13 of the 14 have their own development departments. A high proportion of this select group of firms professed interest in the foundation of a national, sponsored research institute. In general, it would seem that they are all imbued with the belief that research work, no matter whether it is done within their own premises, by a research association, or by sponsored research, is essential for their well-being, and that to take the fullest advantage of it an adequate staff of academically trained men and women is necessary.

There is, of course, little merit, and certainly no advantage, in merely belonging to a research association ; practically any firm, providing that it fulfils the conditions of membership laid down in the association's rules, can do so by paying a subscription. What really matters is the use to which such membership is put. How frequently in practice do firms consult the association ? Do they receive visits from the association's liaison officers, or do they merely pay their subscription, receive the association's publications and make little attempt to use what may be available in the way of scientific information and help ?

For the purpose of discovering to what extent firms made use of their membership, each was asked how frequently it did consult the research association, what method was used to do so, and whether there was an exchange of visits between

the firm's technological staff on the one hand and the research association's liaison officers on the other.

As regards consultations with research associations as a whole, it was found that the majority of the member firms instigate these on their own initiative, the highest percentage being in the case of the British Cotton Industry Research Association ; in other cases, however, the first consultations had been the result of an invitation or encouragement from the association concerned. Member firms are regularly informed of the services which they can receive and many take active steps to ensure that full use is made of them. It is still the case, however, that a large number of members of research associations show little realization of the full extent of the scientific help and other services which their particular association can afford.

Firms in the engineering groups seem to use their research associations for consultation to a lesser extent than do those in the other groups, in that only 68·5 per cent. of the firms in this group said they did so as compared with 96 per cent. for textiles and 95 per cent. for the modern industries. There is a marked tendency for the larger firms to consult the research associations more frequently than do the smaller ones with under 500 employees. The overall picture is that 86 per cent. of the member firms really do consult their research associations, and are not merely passive subscribers.

Thirteen firms whose membership of research associations is through a trade association are mainly smaller firms in the engineering group, and in no case was any frequent or intimate contact with the research association evident.

There is no very significant difference between the proportion of members consulting the Shirley Institute and those consulting other research associations more remote from the area covered by the investigation. The frequency of consultation is perhaps not quite as high with the research associations located at a distance, and there is a clear indication that more members receive visits from the liaison officers of the Shirley Institute than from other associations. This is only to be

expected when a liaison officer from Shirley can visit three or four mills in the same district in one day, as compared with visits from another association which may entail a considerable journey and possibly only a single works or factory to be seen at the end of it. But the information given to the investigators shows that member firms who may be a long way from the laboratories of their research association do not on that account fail to apply for, and to receive, assistance.

The policy and programme of a research association is formulated by the industry it serves through the medium of a governing council appointed by the member firms. Seventeen of the firms visited had representation on the council of their appropriate research association, whilst others were represented on committees or sub-committees set up to advise that association on some particular aspect of its activities. These firms, together with some others which had co-operated with the associations by trying out in their works some new plant or process devised in the laboratories, were the clearest and warmest in their comments on the investigators' questions on this subject. This fact tended to confirm the feeling the investigators had at the outset, namely, that it is when a firm has really intimate and constant contacts with its research association that the fullest benefits arise.

Concerning the degree to which visits are exchanged between members and their associations, it was found that 56 per cent. of the members visit their research associations and 60 per cent. receive visits. The most significant fact which comes to light is that so far as visits to a research association are concerned, its location is relatively unimportant. The textile industry does not show a great predominance in this respect even though the cotton, rayon and wool research associations are within easy reach of Manchester. There is, however, some advantage where visits from the research association are concerned, and it will be seen that 81 per cent. of the members in the textile group receive visits, compared with an average of 51 per cent. for the other three groups.

It is perhaps not without significance that the textile group

of firms, which shows the lowest proportion of scientists/technologists, is the one which has the highest proportion of membership and consultations with its research association.

Apart from the cases in which certain firms had specially close relations (referred to earlier), the consultations described to the investigators were usually of an *ad hoc* nature. At times firms discussed their long-term projects with their research associations, but the investigators were left with the impression that many firms appeared to fear that, by discussing such matters, they would reveal the lines upon which their new developments were moving and that these might unwittingly be passed on to competitors who were also members of the same association. This secrecy complex was more apparent in some industries than others, but it existed to some extent in all, and is clearly a factor in relation to whole-hearted co-operation with research associations in the development of research projects initiated by individual firms.

It cannot be too strongly stressed that no criticism of the integrity or discretion of research association staffs was ever suggested or implied. The feeling, however, clearly existed that where such activities were being undertaken, the fewer people knowing about them, until the firm concerned was ready to launch their developments commercially, the better. Not all firms held this view, and a few examples were given of help received from a research association where this had been sought by firms in respect of their individual development projects. One firm had profited considerably from regular consultations regarding the purification of the effluent from their factory, and the removal from it of waste products which were subsequently converted into valuable by-products. Another had made use of basic research data from research associations to help in the design of arc-breaking oil-immersed switch contacts, and still another had been helped in connection with apparatus for the metering of liquids flowing in pipes.

Even in these three examples, however, the investigators doubt if a completely free and open discussion of the project

as a whole had taken place between the firm and the association ; only that particular phase on which enlightenment or help was required seemed to have been revealed in detail.

A further illustration of this reserve on the part of industrialists concerns a firm which had decided to develop a new type of welding machine for use in its own shop. A research association was consulted regarding the electrical accessories required and recent innovations in the field of induction heating. Precise details of the improvements to the machines which had been effected by the firm's engineers were, however, neither discussed nor disclosed, the consultation being confined strictly to the specific objectives of the inquiry. Another example may be cited as showing how one research association had provided help in a most practical manner at the request of one of its members. The firm concerned was most anxious to increase its productivity and the research association's assistance was solicited. The association sent a team of experts to the works and made a thorough examination of the production methods employed. As a result of this investigation, certain recommendations were made, and adopted, the increase in production which resulted exceeding the firm's highest expectations.

Ad hoc queries reported to the investigators were both many in number and diverse in nature, but were often concerned merely with day-to-day production problems and " trouble-shooting." Advice would be requested on a difficulty which had arisen in operation ; or perhaps faulty goods or some persisting defect in quality made it imperative to find the cause and to rectify it. Sometimes an article was returned by a customer with some complaint about quality or performance, and the firm, having diagnosed the trouble to the best of its ability, asked the research association to confirm or amend its findings. Other queries were of a more general nature and asked for definite information on a particular subject, or where, and from whom, the best and latest information could be obtained. As the investigation proceeded it became in fact clear that a very large number of firms looked upon the

research associations chiefly as trouble-shooters and information bureaux for themselves, and did not see them as establishments mainly devoted to research and development activities likely to be of value to the industry as a whole.

Firms not Members of a Research Association

It may not be without value to consider what the investigators gathered from their discussions with firms which are not members of a research association although one appropriate to their industry does exist. Twenty such firms were encountered and, of these, 12 gave reasons for, or comments on, the position they had adopted. The firms in general were small, 18 out of the 20 having less than 500 employees ; most of them had a low proportion of scientifically or technologically trained men in their employ—only 6 had a graduate ; none of them had a research department, but 6 were equipped with development departments which undertook investigations and experiments of direct interest to the firm, and these were, for the most part, well organized and efficient.

The industries covered by these firms included, among others, light engineering, small jobbing non-ferrous foundries, the manufacture of metering equipment and electrical accessories, and the production of ceramics, leather and paper. Two small textile firms engaged in weaving and finishing were also included, and one of these signified its intention of applying for membership of the British Cotton Industry Research Association in the near future. Of the 12 firms who indicated their reasons for not joining the appropriate association, 4 considered that they were ahead of their competitors in fundamental knowledge and practical experience. They were satisfied that there was no advantage to be gained by membership. A fifth firm stated that it obtained all the scientific assistance it needed from the suppliers of its raw materials. These 5 firms, in fact, were satisfied in their own minds that they had access to sufficient scientific knowledge and technical information to make membership of a research association

unnecessary. The investigators, having regard to all they heard, would not take this view. Even large firms with efficient, well-organized research and development sections which keep them ahead of other firms in the industry, and perhaps in some particular aspects even ahead of the research association itself, still derive advantages from a study of the association's publications and from opportunities for discussion of matters of mutual interest with other experts which membership affords.

The remaining 7 of the firms which gave reasons for not participating in the research association movement did not claim that they had all the scientific knowledge their business demanded. Four of them considered they would not obtain value for their subscriptions. Two considered that, with their lack of scientific and technological staff, they would be unable to appreciate the research association's work and did not feel that they could afford a man with the scientific background to interpret it. Another small firm felt the cost of membership to be a barrier. In all seven cases the real reason behind the firm's decision seemed to be an unwillingness to pay the necessary subscription.

Although no definite reasons were given by the other 8 firms, it was clear to the investigators that 5 of them were unambitious in their outlook and in their attitude to technical progress. The other 3 were progressive firms intent upon developing their own ideas and managed by men of initiative and resource who were confident that they could get their problems solved either by their own effort or by knowing where to go for scientific assistance and advice.

Studying these reasons put forward by firms not linked to the research association movement, it seemed evident that they can be divided into two groups. The first group includes firms which deem themselves to be self-sufficient and, while not decrying the work done by the associations, consider that these associations have little to offer to a firm well staffed with scientific and technological personnel and with a background of accumulated knowledge and experience. The second

section comprises firms of a lower status, not so alert for opportunities of advancement, and inclined to adopt an attitude of indifference towards the research associations, leading the impartial observer to believe that they are lacking in a progressive outlook. Save in the case of the very small firm, which felt the subscription was too high to make membership an attractive proposition, it is doubtful if any of these non-member firms had a valid reason against membership. It is worthy of note that in no case did a firm withhold its support on the grounds that the research association's work was either misdirected or misconceived.

The opinions of member firms on the work done by the research associations and the services offered were for the most part extremely friendly and appreciative. The opinion was often expressed that they were of great value to the industries which are served, and these associations are clearly highly esteemed by a large proportion of industrial executives. Different firms have varying needs for scientific knowledge, and look to the associations for guidance in very different ways. A large firm with its own scientific staff and well-organized research and development laboratories, will gain most benefit perhaps by means of general discussions and meetings with the research association staff. New developments and trends in the industry can be reviewed, and ideas and suggestions can be exchanged on the problems which need to be tackled for the progress of the industry as a whole. A smaller firm without the same internal facilities may rely on the association more for help in particular scientific and technological problems, and will hope to be kept abreast of modern ideas and developments by a study of the literature published. Firms which by the nature of things have little claim to scientific or technological pretensions, but which nevertheless take their place most usefully in the economy of the nation, may find that the association's technical advisory service is to them of major importance.

Firms criticizing Research Associations

It is noticeable that firms which never consult their research association make no criticisms of them, probably because, due to lack of contact, they have no opinions to express. In these cases some efforts were made by the interviewers to encourage a visit to the association so that the work being carried on, and the assistance available to members, might be fully demonstrated.

As might be expected, more criticism was voiced by firms where contact with their research association was infrequent, but the total numbers of such firms is comparatively small. Nearly all the firms which never consult their research association fall in the engineering and miscellaneous groups. The frequency of consultation rises in all groups of industry with an increase in size ; 21 per cent. of firms in the smallest size-group have frequent consultations, whilst in the largest size-group 79 per cent. of the firms are so classified.

Considering the many and varied functions which the research associations undertake, it speaks well of their work that so few adverse criticisms were voiced, and that even these were mostly of a minor character. In general, the publications issued by the associations were held in high regard and were considered to be most valuable for reference. There were, however, a few firms who thought that the associations aimed at rather too high a scientific level, and who thus felt that there was little in their publications of value to the practical plant manager and even less for foremen or overlookers. Others were of the opinion that such a spate of literature was published that it was impossible to study it with due care, and difficult even to sort out those articles and references worthy of the firm's closer attention. All they could hope for was that in circulating the journals to executives and managers, appropriate items would be picked out by someone or another. Such firms would very much appreciate a " canalization " of the reports so that, for instance, a firm engaged in weaving would receive only the literature relating

to weaving and not a great deal which was relevant only to other sections of the textile industry.

Certain firms suggested that queries sent to research associations were not always answered as promptly as industry expected. This did not refer to cases where information of a general nature was requested, but to queries relating to the examination of a suspected raw material or product, or to some snag which had appeared in the course of manufacture. Obviously, the sooner replies are received to such requests the better, but the investigators felt that often those making criticisms of this kind had little understanding of the time taken by laboratory work and failed to realize the difficulty of organizing a laboratory economically if it is to be ready to meet unpredictable demands at a moment's notice.

The criticism relating to the scientific level of the work done by the research association laboratories has already been mentioned. The opinion was expressed that it was too academic to be of use to industry and that the association's personnel had not sufficient practical experience to appreciate industry's problems and difficulties. The same critics were apt to assert that liaison officers from the research associations, having insufficient industrial background, gained more from industry as a result of their visits than they had to offer. More than once the opinion was voiced that work on technological problems received too little attention in favour of increasing scientific knowledge for its own sake. Although in the abstract the latter was highly commendable, it reduced the immediate practical advantages of membership, and it was suggested by these critics that the research associations might well strengthen their technological and liaison activities. Such strengthening of the technological work of an association can only be accomplished in one of two ways—either by the diversion of men and money from its scientific research, or as an addition to the research association's programme. If the latter course is adopted, more money must be found in order that a greater number of technologists can be employed and offered remuneration at a rate which will attract men of

the highest calibre. Seriously to restrict scientific work in favour of the technological would be a retrograde step, and would tend to undermine the very foundations on which the research associations are based. An increase in income, on the other hand, can only come from members' subscriptions and, if there is a strong demand by members for still better liaison and technological service, the solution surely lies in their own hands.

It must be remembered that the investigators came upon their informants as visitors specially charged to seek information. A faint implication may have been created that criticisms of any of the relevant institutions would be of interest, and undoubtedly some of those interviewed set out to comply. In no instance, however, was it found that a member of a research association had felt strongly enough to press his criticism of the work or policy before the governing body, or, having done so, to have come away seriously disgruntled, or deeply at variance with the association. This seems to put the criticisms just recorded in their true perspective. Many of them arise from what can only be regarded as a narrow claim that the particular section of industry with which a firm is concerned, or its own particular needs, should dictate the nature of the work and service of the association, or else from a failure to appreciate the very reason for the founding of a co-operative research organization.

The part played by research associations in the everyday work and development of industry is clearly considerable, and their influence is widespread and appreciated. However, it would be wide of the mark to assume that when an industry has equipped itself with a research association it can then be taken for granted that the contribution which science is capable of making to the progress of that industry will follow as a matter of course. All that has been achieved is that firms have better opportunities of absorbing some of the resources placed at their disposal. It is still the case that the degree to which such absorption takes place must in the end depend on action by each individual firm.

There are some aspects of the application of science to industry in regard to which a co-operative research association can do little. Even in those directions in which the association can diagnose and prescribe with perfect relevance to the practical needs of the industry, it still remains a fact that only the individual firms can carry the prescription into effect.

The number of firms in the cross-section of British industry covered by the investigation who could claim that there was no research association working on the problems of their branch of industry—23 per cent. of the whole—is a sobering thought for anybody who might be tempted to assume that the research association movement presents us with a solution of the problem of providing *all* industry with the scientific information and knowledge it ought to have.

After the passing of a number of years, a well-supported, well-directed research association can accumulate a large fund of scientific knowledge relevant to its materials and processes ; can confidently expect to discover profitable solutions for some at least of its chronic technical problems ; can rely upon the introduction into common practice of a growing number of scientific or technical innovations leading to improved quality or to economy, and can be sure its own technologists will be stimulated and aided by a regular stream of scientific work in their field. To ask for more from the research association movement would be irrational : even the benefits mentioned can only come after the lapse of time, and in strict proportion to the amount of money provided for staff and experimental expenses.

Where an industry has no research association, some similar advantages may arise from other research activities, but it cannot be the case that such an industry will have them either as abundantly or so well designed for its needs.

These things are realized in industry by the best-informed managements who give praise where praise is due for the benefits of the research association movement without criticizing it for a failure to achieve what it was never intended to perform, or blaming it for gaps in the provision of the

resources of science for which, by its nature, it cannot be held responsible.

Attention may, in conclusion, be drawn to two points in connection with those firms whose main product is not covered by a research association, under which heading two firms in the textile group are recorded. These two firms, however, are engaged in industries which, though included in this category by the Board of Trade Standard Industrial Classification, are actually far removed from the conventional conception of the textile industry. This is but one of the many instances encountered by the investigators of the great variety and complexity of modern industry, a fact which often makes it exceedingly difficult for the statistician to group certain

MEMBERSHIP OF RESEARCH ASSOCIATIONS OF FIRMS VISITED
(151 of the 225 firms visited are members of at least one Research Association)

British Cotton Industry Research Association	59
British Cast Iron Research Association	17
Research Association of British Rubber Manufacturers	14
British Rayon Research Association	13
British Electrical and Allied Industries Research Association	9
Printing, Packaging and Allied Trades Research Association	9
British Non-Ferrous Metals Research Association	7
Research Association of British Paint, Colour and Varnish Manufacturers	7
Hosiery and Allied Trades Research Association	6
British Leather Manufacturers' Research Association	6
British Paper and Board Industry Research Association	6
Production Engineering Research Association	6
Wool Industries Research Association	6
British Baking Industries Research Association	4
British Boot, Shoe and Allied Trades Research Association	4
British Food Manufacturing Industries Research Association	4
British Ceramic Research Association	3
British Launderers' Research Association	3
Fruit and Vegetable Canning Research Association	2
British Iron and Steel Research Association	2
Linoleum and Felt Base Research Council	2
Motor Industry Research Association	2
British Scientific Instruments Research Association	2
Coal Tar Research Association	1
Research Association of British Flour Millers	1
British Gelatine and Glue Research Association	1
British Hydromechanics Research Association	1
British Welding Research Association	1
Total	198

units together for the compilation of his tables. Most of the firms whose production is not covered by a research association are small, 44 out of 50 having fewer than 250 employees. They are for the most part engaged in manufacturing one or two specialized products on a relatively small scale and differ, therefore, from the large firm manufacturing a variety of products where there is a much higher probability that at least one of these will be catered for by a research association.

The table on page 71 sets out, in summary form, the information gathered concerning membership of research associations.

Tables 24–29.

CHAPTER V

THE UNIVERSITIES

THE function of this chapter is to consider the information obtained regarding the nature of the relations between the universities and industry, and whether these are sufficiently intimate to ensure that the best possible use is made by industry of the scientific knowledge which is there available.

The contacts between industry and the universities to be discussed are the formal ones made by the firm and well known both to management and staff. That there are many informal communications between members of staff and their former tutors and professors is, of course, well known and a large amount of information undoubtedly reaches industry through such channels. It is not possible, however, to trace most of such contacts and the facts elicited by the investigators are, therefore, necessarily confined to details of more formal and official liaison.

It became evident at an early stage in the investigation that it would be well to divide the active contacts between the firms and universities and colleges into two classes : firstly, those relating to scientific and technological problems, and, secondly, those arising in connection with the recruitment of staff, the former outnumbering those on recruitment in the ratio of 77 : 57.

Firms grouped as modern industries appear to approach the universities most frequently, but the other groups are well represented. Even the textile industry, which makes the fewest contacts, is still fairly well represented, a quarter of the textile firms visited having some active link with university personnel. At first sight this might appear somewhat surprising in view of the presence of the Shirley Institute in the immediate vicinity, but over half the technical consultations reported to the investigators were with the University of

Leeds and are on matters connected with wool and not cotton.

Forty per cent. of the firms covered by the survey reported that they had active contacts with some university or technological college. In some cases these contacts were regular and intimate, in others somewhat casual. Whatever the nature of the contact or its subject, however, this figure of 40 per cent. gives an indication of the very considerable extent to which industry in Greater Manchester is in touch with the universities, even though it gives no precise measure of the strength of the links.

The size of the firm seems to have a considerable bearing on whether or not it is likely to be found amongst those in regular touch with universities : 19·5 per cent. of the firms with 50–100 employees are so recorded, a figure which rises to 68 per cent. when firms with over 1,000 employees are considered. This trend is equally noticeable whether the contacts are on scientific and technological matters on the one hand or on recruitment on the other. Closer examination of the records shows that this increase is closely related to the correspondingly increased proportion of graduates in the firms of larger size. Consultation with universities rises from 33 to 93 per cent. as the number of graduates rises from 1 to over 17.

On the other hand, no less than 20 per cent. of the firms with no graduates at all have sought help from a university on scientific and technological problems and 8 per cent. on recruitment. The assistance of the universities is, therefore, at times sought even by firms with the most modest of scientific pretensions. Ten of the firms who have consulted the universities on recruitment have no graduates in their employment, an apparent anomaly arising from the fact that they had recruited graduate staff which at the time of the inquiry had left and had not so far been replaced.

Consultation

Just over half the firms which turned to the universities from time to time said that their contacts covered both scientific and recruitment problems, whilst the remainder had consultations on scientific matters or on recruitment but not on both. It seems desirable to consider, first of all, those approaches made on matters of a scientific or technological nature, and then follow with an account of the extent to which the universities are consulted on recruitment. Other factors such as the reasons for the choice of a particular university, the nature and intimacy of the contact and examples of the problems discussed will then be touched upon.

In a concentrated industrial area such as Greater Manchester, with a university of high scientific reputation at the hub, industry, in general, feels little need to look further afield for its contacts with university personnel and resources. All that is required is right on the doorstep, either at the University itself or at the College of Technology, and opportunities for meetings, visits and personal introductions are readily at hand. Moreover, in the firms visited, a considerable proportion of the scientific staff engaged in the local industries have graduated at Manchester and have maintained their university associations in after years. It was to be expected, therefore, that Manchester University and College of Technology would take precedence over all others when it came to recording those universities with which contacts were most frequently mentioned. The University of Manchester and the College of Technology are closely integrated, the latter being the Faculty of Technology of the University ; no distinction has, therefore, been made between the two so far as the consultations recorded are concerned.

The position may be summarized by saying that of the 89 firms which consulted a university, 70 went to Manchester. Of these 70 firms some had links with other universities as well, particularly when the question of recruitment of staff arose ; but these figures are significant in showing that it is

mainly to the University of Manchester that the firms covered by the survey turn. Only two factors influenced the remaining firms in their choice : either the university approached had a national reputation in that particular branch of science of most immediate interest to the firm, or it was the *alma mater* of one of the directors or senior staff.

It was to be expected that the inquiries put to the firms regarding their associations with university personnel, and the calls made upon university resources of scientific knowledge, would lead to a wide diversity of replies depending largely on the nature of the industry in which each firm was engaged, and this indeed proved to be the case. Certain firms were encountered which valued advice from the academic world so highly that they retained the services of university staff as permanent consultants, endowed research scholarships, or financed research projects of mutual interest. In the latter case, the university reserved the right of its members to publish the results should they consider it desirable.

At the other end of the scale were found those firms which did not require regular consultations and which, by virtue of the position they filled in the industrial jig-saw, had no incentive to undertake, or to finance, research work of a fundamental nature. Some firms with no scientific equipment of their own reported that they occasionally sought help from the universities and colleges for tests which required the use of instruments or other equipment of an uncommon type. Work of this nature is really the province of the industrial test house and only in exceptional circumstances is the department of a university in a position to assist industry in this way. The investigators found a fairly large number of firms who had turned to a university when requiring help in solving specific problems which might be hindering their research and development projects, or were interfering with their production programme. Other firms said that they found periodic visits to a university for informal talks on general scientific matters with some member of staff known to them personally, to be a most fruitful source of new ideas and information.

One of the more striking features which has emerged is the almost complete unanimity of the firms enjoying association with university resources, on the value of a personal contact with, or the friendship of one of their leading men with a member or members of the academic body. No matter whether the firm was in a position to retain the services of university consultants, to support research of mutual interest, or merely to raise some query regarding one of its raw materials or products, in nearly every case the attention of the investigators was very particularly called to the fact that the firm's relations with the university faculty or department were founded on a basis of personal friendship. It was rare indeed to learn of a consultation which had been strictly official and impersonal. Frequently, the personal touch was the result of a former student having maintained his connections with his university or college after graduation. Sometimes it had developed as a result of wartime associations at committees or meetings at which industrialists and professors had sat round the same table; but, whatever the origin, time and time again it was stressed how highly such relationships were esteemed by industry, and how beneficial they had proved, largely on account of their informal, personal nature.

Eight of the 225 firms visited had a very close relationship with one of the universities in that they retained consultants or supported research at the University. In view of what has been said earlier, it might not have been surprising if all the eight had been found in the modern industries group and only in the larger size categories. They proved, however, to be engaged in such diverse industries as chemicals, engineering, textiles, leather, glass and linoleum. All eight had found it advantageous to finance research at a university, two firms had retained the services of a permanent consultant, and one had endowed a Chair in the particular branch of science most closely connected with its own business. In every case the firms were satisfied with the results of their expenditure. They appreciated that such an alliance did not end when a particular research was completed, but laid a foundation for

a permanent liaison which was invaluable. These outstanding examples of partnership between the research laboratories of a university and firms in industry, so it seemed to the investigators, could hardly have been bettered at home or abroad. Not every unit in industry, of course, would find such an intimate contact profitable ; to many, no doubt, it would be financially impossible, but the thought does remain that perhaps some of the other firms in the area would find the deliberate cultivation of closer relationship with one or more of the universities a policy yielding rich, long-term satisfaction.

What of the firms having scientific and technological ties with the universities but not of such a highly developed character ? Rather less than one-third of these sought help with analytical or testing procedures of a somewhat specialized nature, involving perhaps spectrographic analysis, X-ray crystallography, or the examination of certain structural materials to determine their resistance to corrosion or erosion. Certain firms in the food and drink processing industries had sought help in connection with tests on the sterility or the vitamin contents of their products. Others, in the engineering field, were in need of tests on prototypes of new or improved lines of production, or had even used pilot plant available at the university for trying out a new process in course of development before putting it into works' operation.

There were a few cases in which requests had been made for simple chemical analyses or for physical tests to determine the hardness or tensile strength of samples, but this was not general and was not encouraged by the universities, who felt such work was outside their province. Such tests are better performed in one of the numerous test houses which specialize in this type of work. It should be clear to industry, and in the experience of the investigators it generally is, that it would be wrong for the universities to allow themselves to be deflected from their main duty of teaching and research, but it may sometimes not be without value to university scientists to study an actual, concrete problem propounded by industry.

With a due sense of proportion on both sides, contacts along these lines can be as appropriate as they have proved fruitful.

Other classes into which firms maintaining scientific contacts with the universities may be grouped, cover those which sought help when a specific problem had arisen on which the need for advice was felt, and others which did not wait for such special occasions but had discussions of a general nature at fairly frequent intervals. In the first of these two groups are to be found firms from every branch of industry, and of every size, the problems submitted being as diverse in character as the firms from which they sprang. Two firms in the chemical industry, for instance, were in regular contact with the Faculty of Medicine at Manchester on pharmacological questions; two others reported that the Universities of Manchester, London, Leeds or Liverpool were consulted—depending on the nature of the problem. Leeds University was approached by two firms in connection with any questions relating to textiles or leather, whilst Manchester was turned to by those requiring advice on metallurgical or welding matters. Consultations were most frequently made on chemical subjects, general engineering, metallurgy and textiles in that order, and Manchester was the university chosen in 58 per cent. of all the cases.

Turning now to those firms which had frequent consultations of a somewhat general nature, it was found that these as a rule consisted of informal talks with professors and other members of the academic staff, and were based on a foundation of personal acquaintance. They were not necessarily confined to matters relating to the firm's industry, but ranged over the whole field of science, and covered many aspects of industry of mutual interest. Great value was attributed to such informal talks, the thoughts they provoked and the inspiration which at times was forthcoming.

Thirteen firms reported that they were in regular touch with a university on these lines, and it seems important to emphasize here that the answers to the investigator's questions

on this subject were all supplied by high executives who could only be aware of such meetings as took place at board or high managerial level. There are certainly very many instances in which a similar exchange of ideas and experience took place at lower levels unknown to the higher executive staff, and there can be little doubt that these, too, must contribute in no small measure to the free flow of scientific information from the universities to industry.

Although the majority of the firms claiming to be in touch with the scientific resources of the universities are at a fairly high level so far as their own scientific personnel and facilities are concerned, it would be erroneous to assume that a highly qualified staff and extensive research or development laboratories are essential before firms can enjoy such friendly contacts. While it is probably true to say that the firm well equipped in these respects will obtain the maximum benefit, ample proof was secured that there are those, with no great scientific resources of their own, who have also profited by the same policy.

It is not always easy for a small firm, with no scientific pretensions, to enlist the interest of the highest academic authorities ; they may not know whom to approach or how to formulate their inquiries. On more than one occasion the information was volunteered that the firm was reluctant to approach a university owing to its own paucity of scientific knowledge, and feared that even if its questions could be formulated satisfactorily, the answers would be beyond their comprehension. Such a case came to the notice of one of the investigators during an interview and he was able to suggest the best method of approach. A few weeks later it was learned that the suggestion had been acted upon and a member of the academic body in the university concerned was already taking an interest in the matter.

In nearly every case encountered, it was found that the board and management were highly appreciative of the help they had received when their problems were put forward. There appeared to be complete confidence that no exposure

of the firm's secrets or processes would result from any such contact, and the firms were not only willing, but even anxious, to discuss their latest development projects with the universities whenever this was possible. Where criticism did arise, it appeared to be based on a misunderstanding of the true functions of a university and the nature of the work it can be expected to undertake. There were no expressions of dissatisfaction at the results of any work which had been carried out, only an occasional regret that a university had been unable to undertake work which had been suggested—arising perhaps from a failure fully to appreciate that with a university it is the academic interest and value of a problem which must be the deciding factor.

Recruitment of Graduates

Earlier in this chapter it was said that more firms consult the universities on scientific matters than do so regarding recruitment. Some companies prefer to engage graduates who are already to some extent familiar with works' methods and practice, rather than those straight from a university or college. Such firms do not, in general, go to the appointments boards of the universitites or even to individual professors when there is a vacancy to be filled, but rely on advertisement, on the Technical and Scientific Register, or on personal knowledge, to satisfy their requirements. The actual figure on this point has considerable interest. Among the firms visited, the universities were used as the recruiting ground for scientific and technological staff by only 57 per cent. of the firms employing such personnel.

It should be noted that since the survey is concerned with the use of science in industry, the statement just made (and others in this chapter) refers only to the recruitment of graduates in science or technology. One or two firms, but only one or two, said that they had recruited an arts graduate and were grooming him for a responsible executive post, expressing the opinion that the training of such a man was an

excellent background for his subsequent entry into administration and general industrial management. They believed that the arts graduate had certain advantages over the science graduate in that his education had been on more general lines than that of a graduate who had specialized in one of the sciences ; this outlook, however, was exceptional and was encountered only in one or two instances.

As was the case in consultations on scientific or technological matters, Manchester University is naturally the main source to which industry in this area turns for its graduate recruits, but other universities with a reputation in some particular field of knowledge are extensively approached. The University of Leeds was sometimes the choice for textiles and leather, of Liverpool for edible oils and fats, whilst in more narrowly specialized industries, such as glass and mining machinery, it was found that the Department of Glass Technology at Sheffield and the Royal School of Mines were respectively the first choices.

It was felt that it would be of interest to inquire from professors and others in the University of Manchester how far their personal experience of co-operation with industrial firms agreed with what had been gathered from those visited. The heads of eight departments at the University and the College of Technology were good enough to respond, either by letter or interview, and it was found that their experience was much in line with the facts already revealed by industry. By far the most usual form of approach is again on a personal basis, from individual to individual, but there are occasions when an official request is made by a firm to the appropriate faculty or department. The head of one department which is in a rather unique position in this respect said that during the past five years 272 firms had asked him, or a member of his staff, for assistance in one way or another. This help they had been able to give, and it is of interest to note that, among the firms covered by the survey, twenty reported that they had approached this department.

It was confirmed that the heads of departments were fre-

quently asked to recommend likely men in their last year for recruitment to industry, and that there was a close collaboration between the appointments board and the departments in this matter. One department reported that they received so many requests for recruits as to be an embarrassment as they had not nearly sufficient candidates to offer.

Summing Up

A few comments may be permitted by way of a general summary of the impressions received, even at the risk of some repetition.

It has been found that 40 per cent. of the firms covered in the survey are not only aware of the resources available to them at the universities, but make use of them in some way or another. Such firms are not confined to any one industrial group, and vary in size from those employing over 2,000 persons to those with less than 100. They include those with large numbers of graduates on the staff and those with neither graduates nor holders of diplomas. In nearly every case it was found that the board and management were highly appreciative of the help they received with their problems, and particularly valued those associations which were based on personal contact and friendship.

With a few exceptions, in which a graduate had been recruited for the production side and did not relish the idea of having to work on the shop floor, or to learn the practical side of the industry from the bottom up, industry was well satisfied with both the keenness and ability of the men turned out from the universities. There is little doubt from what was said to the investigators both from the industrial and university sides, that there is a shortage of graduates in industry and that demand is keeping well ahead of supply. There is, therefore, plenty of opportunity for an ambitious young graduate, provided he realizes—as he normally does—that his university training is only the first rung of the ladder and does not expect it to qualify him automatically for high

executive office. He may well be encouraged by a knowledge of the relatively high proportion of graduates who have won places on boards of directors solely by virtue of their own ability and diligence.

Manchester University and College of Technology were the sources from which assistance was most frequently sought, the branches of science mostly concerned being engineering, chemistry and metallurgy, in that order. It is of interest to note that 59 firms had consulted these institutions on scientific and technological problems, of which 28 were referred to the University and 31 to the College of Technology. The departments concerned and the number of firms consulting them are set out in the short table below.

NUMBER OF FIRMS HAVING CONSULTATIONS WITH FACULTIES AND DEPARTMENTS AT MANCHESTER UNIVERSITY

Faculty of Technology (Manchester College of Technology)		Other Faculties and Departments	
Mechanical Engineering	20	Chemistry	11
Applied Chemistry	8	Metallurgy	10
Textiles	3	Medicine	3
		Electrical Engineering	3
		Education	1
Total	31	Total	28

Turning now to the universities other than Manchester, it was found that Leeds was approached most frequently. Twelve firms, mainly in the textile and leather industries, made Leeds their first choice, and were full of praise for the work done in their particular field. Four firms in the engineering industries had a close liaison with the University of Sheffield and one, in the glass industry, paid special tribute to the Department of Glass Technology there which serves not only as a training ground for technologists but has, to a large extent, taken the place of the, now defunct, research association. Four firms were in close contact with Cambridge on electrical or chemical problems, 4 with Liverpool on chemical

matters—mainly in connection with edible oils and fats, whilst in two cases Birmingham University was chosen when the advice required concerned chemical problems. Cardiff, Glasgow, London, Newcastle and North Staffordshire had also been consulted from time to time. Industry in Greater Manchester clearly does not limit its association with the universities to those in the immediate neighbourhood.

So far as the universities are used as recruiting centres, all, save 6, of the firms asking university appointments boards to recommend graduates, applied to Manchester ; of the 6 who went elsewhere, 5 said that they did so because they believed the training in those universities was best suited to their own requirements, while in the sixth case, the technical director said that he always approached his own college in London.

Tables 30–35.

CHAPTER VI

OTHER SOURCES OF INFORMATION

THE preceding chapters have dealt with the staffing of industry by scientifically and technologically trained men ; with research and development, and with the nature and extent of the relations which exist between the firms visited and the universities and the research associations. It is now intended to turn to other sources of scientific and technological knowledge which are available and to give some impression of the use to which they are put by industry in the area surveyed. These sources, both numerous and widely divergent in character, range from renowned government laboratories, such as the National Physical Laboratory, to small technical libraries and periodicals. Hardly a single interview failed to add to the list of sources of scientific information used by some particular firm, and by the time the final visit was completed the total was not far short of 100. By grouping those of a similar type together, they have been condensed under nine main headings which cover all the examples brought to the notice of the investigators.

These nine groups are as follows :

1. The Department of Scientific and Industrial Research, and other government-controlled organizations.
2. The National Research Development Corporation.
3. Sponsored research, and scientific and technological research institutes run on commercial lines.
4. Trade associations and similar organizations.
5. Consultants.
6. The suppliers of raw materials or plant, and the customers of the firm.
7. Associated firms in the United Kingdom or abroad, or friendly firms in the same industry.
8. Scientific and technological societies and institutions.
9. Libraries and the scientific and technical press.

A few firms have found deficiencies in the availability of scientific information and considered that information services were inadequately provided in Great Britain. Others told the investigators that there were certain specific problems to which they had been unable to find an answer and did not know whom to approach for assistance. In the main, however, the impression was gained that industry as a whole was satisfied with the adequacy of the available sources of scientific and technological knowledge and advice.

From the firms visited, the investigators gathered the impression that many firms make only a limited use of these sources of information, and that the majority were in somewhat of a groove and relied too much on the one or two contacts which had served them well in the past. When asked how they obtained information, they would reply: "We always go to the research association." "If we don't know we ask our trade association to find out for us," or "We ask our suppliers." It was exceptional to find a firm asserting: "If we don't know we find the most competent authority and so obtain really expert advice on our specific problem!"

Admittedly, firms may be unaware of the existence of the source most likely to solve their difficulties. They may feel that they have no one on the staff with the time to make new contacts, or they may prefer to have a close association with one or two external sources, submit all their inquiries to them, and then leave them to make what further contacts are necessary. Whatever the reason may be, it is difficult to believe that it would not be more satisfactory to make a direct approach to the most competent quarter rather than through an intermediary. It is not in the nature of things for any one body to be an authority on all scientific and technological matters, and if, for example, a research association is asked a question which it does not feel competent to answer, it would seem better in the long run to advise its member accordingly and at the same time put him in direct touch with an acknowledged expert.

From a perusal of the following sections of this chapter it is possible that some firms may be able to find a source of information which satisfies the requirements of which they were not previously aware, or had not considered using. Should such a study not bear fruit, the Manchester Joint Research Council is always ready to give assistance. It may not be sufficiently widely known that the Council has a liaison service which specializes in assisting firms to find the organization best qualified to give help in the solution of specific problems, a service open to the whole of industry whether it supports the Council financially or not.

Department of Scientific and Industrial Research and Other Government-controlled Organizations

The Department of Scientific and Industrial Research, in addition to giving financial aid to the co-operative industrial research associations, has fourteen research organizations of its own, which it has founded, or for which it has assumed responsibility. These organizations cover a very wide field and not only publish reports and abstracts covering their own subjects, but are available for consultation by firms either through the parent department or by direct contact with the establishment. This service of the individual establishments is supplemented by the Intelligence Division at the headquarters of the Department, whose special task it is to assist inquirers seeking advice on the best means of dealing with their scientific problems.

Twenty-two firms visited had approached the Department of Scientific and Industrial Research, or one of its research establishments, for assistance of this kind, whilst several reported that they had derived great benefit from a study of the publications of the Building Research Station, Watford, or the Forest Products Research Laboratory at Princes Risborough. As would be expected, those firms which used the Building Research Station were all closely connected with

that industry, either as manufacturers of building materials or as contractors, whilst the Forest Products Research Laboratory was approached by firms in the timber trade when advice was required on such problems as seasoning, preservation or pest control.

The National Physical Laboratory had undertaken work on the calibration of instruments, and in another case had given very beneficial help and advice on metallurgical questions. Another firm had received valuable aid from the Fuel Research Station in the design of new domestic heating appliances, while still another, which had been in close contact with the Station during the war, had maintained that link when it turned over to peace-time production. The Directorate of Hydraulic Research was consulted by a firm making measuring and metering apparatus on a question regarding river erosion and the silting of estuarial tideways.

These firms are confined almost entirely to the modern, engineering and miscellaneous industry groups, the textile industry being represented by two firms only, these two being engaged on contracts for the Ministry of Supply, from whom they have had considerable assistance and advice.

Of the firms concerned, those which had solicited help from the Department of Scientific and Industrial Research or its associated organizations are shown in the short table set out below.

D.S.I.R. and Associated Organizations Approached

D.S.I.R. Intelligence Division	6
Building Research Station	6
National Physical Laboratory	4
Forest Products Research Laboratory	3
Fuel Research Station	2
Directorate of Hydraulics Research	1
	22

All the firms were very satisfied with the results of their inquiries, and highly appreciative of the care and attention

given by the establishments approached, but it is, perhaps, a little unexpected that only five of the fourteen research organizations controlled by the Department of Scientific and Industrial Research appear to have been so consulted.

A number of firms reported that they were working in close co-operation with the Ministry of Supply or the Service Departments. Some were engaged on government contracts, while others were undertaking development work on their behalf. In all cases, free exchange of information and experience took place between the firm and the research departments of the Ministry and Services, but no details were available in these cases as the projects could not yet be discussed.

The National Research Development Corporation

This organization, which was set up in 1949 as a result of the passing of the Development of Inventions Act, 1948, has, as its main objective, the development and exploitation of inventions and ideas which, without its aid, would probably not be developed in this country.

The present survey seemed to offer a good opportunity of finding out how widely the Corporation is known and used, and at the same time of publicizing its activities. With these objects in view, each firm was asked whether it was aware of the existence of the National Research Development Corporation, had it put or received any proposals, and if so, had use been made of them and, finally, if the firm was previously unaware of its existence, would it now like to get in touch with the Corporation. In cases where the answer to the last question was in the affirmative, the firm was given a short memorandum setting out the objectives of the Corporation so that a direct approach could be made.

The replies that were received showed that only 17 per cent. of the firms were aware of the existence of the Corporation and of the scope of its work, and of these over half were of the opinion that it could be of no service to them. A more encouraging response was received from those to whom the

National Research Development Corporation was previously unknown and a number of such firms expressed a desire to receive fuller details of its work. A few firms said that they had received definite proposals, but none of these had, as yet, been taken up. Details of such proposals were not disclosed, but it was made clear that the firms' action was dictated by circumstances, and cast no reflection on the quality of the ideas or inventions put forward for consideration. In some cases the propositions received were not suitable for adoption in that particular section of industry, whilst in others they could not be developed without an undue interference with the existing production programme of the firm.

Firms in the modern industry group showed more interest in the work of the Corporation than did those in the other three groups, and had received more proposals from the Corporation.

The analysis of the firms by size-groups is of interest in that it shows that a higher percentage of firms in the larger size-groups were already aware of the N.R.D.C. When, however, the aims and functions of the Corporation had been explained to the firms to which it had been so far unknown, it was found that it was the smaller ones who expressed the more definite interest in its activities.

Although only some 25 per cent. of the firms said that they would be interested in receiving details of new inventions and processes from the Corporation, this does not necessarily mean that its work is not appreciated by industry in the region. The very nature of the industrial pattern of the region precludes many firms from active participation in the development of projects sponsored by the Corporation, and such firms form a very large proportion of those who said that they could not see how they were likely to benefit from its work. The strong impression remained that the National Research Development Corporation is not yet sufficiently widely known to play effectively the part it was created to fulfil.

Sponsored Research

Twenty-eight firms have either used sponsored research or expressed opinions in favour of the foundation of a national sponsored research institute. Of these, 8 have already used the sponsored research facilities at present available, and consider them satisfactory for their needs. The remaining 20 favour the foundation of a new, national institution. The modern industry group predominates in this wish for further facilities for sponsored research and there is a tendency for such interest to increase as the firms become larger. The presence of directors or staff with degrees, and the existence of research departments either at the establishment, or at an associated firm, seem to be directly associated with the interest in this form of research.

It was found that, while there is no apparent difference in the interest expressed in sponsored research by those firms with a membership of up to two research associations, the firms who are members of three or more show a highly significant rise. The very small firms are almost completely uninterested in facilities of this nature. There seems little variation in the interest shown by the intermediate and larger size-groups, and though interest shown by the modern industries seems somewhat higher than that of the engineering industries, the difference is not particularly significant.

As has already been mentioned, sponsored research is not used to any large extent by the firms covered in this survey. Apart from those which had financed research at the universities, there were three firms which said they used a research association for this purpose and only one that had approached an organization which undertakes sponsored research and development as a commercial proposition. The one firm reporting such dealings was emphatic in its praise of the way the work was carried out, and of the results achieved. Organizations of this nature are not developed in Britain on the same extensive scale as in the United States, and this may be one reason why this source of scientific knowledge is unused.

Sir Edward Appleton, speaking at Manchester in October 1946 (Manchester Joint Research Council Communication No. 2), said that if there were a real need for an institute on the lines of the Mellon Institute in America, the Department of Scientific and Industrial Research would not hesitate to go ahead with plans for such a project. The present survey seemed to afford an excellent opportunity of obtaining the reactions of a fairly typical cross-section of industry to such a proposition. Each firm was, therefore, asked whether it saw a place for an institute which would undertake sponsored research on a national scale similar to the Mellon and Battelle Institutes in the U.S.A. and, if such an institute were available in this country, whether the firm would be likely to take advantage of its facilities.

The answers received are summarized below.

VIEWS OF 225 FIRMS ON PROVISION OF A NATIONAL SPONSORED RESEARCH INSTITUTE

	Number	Percentage
Firms stating that they would use such an institute	20	9
Firms doubtful, but which considered such use possible	34	15
Firms seeing no use for their own needs . . .	171	76
	225	100

Every firm, including those seeing no probable use for a sponsored research institute for their own needs, said that such an institute would be an asset to industry as a whole, but the impression was gained that if industry were asked to bear a proportion of the cost of such an institute, only the twenty firms expressing their definite desire to use it would be likely to give the proposition any practical support and that only intermittently or rarely.

Some of the reasons which influenced these firms to support the idea of a sponsored research institute are of sufficient interest to include here and may serve to stimulate further

thought on the subject. The two factors having the greatest influence were, firstly, the knowledge that the results of any work done would belong to the firm alone, and that the institute would be particularly careful to ensure that the nature of the work would be kept secret. Secondly, that it would permit a firm's special research problems to be pursued extramurally ; work which otherwise might interfere with their own internal research and development programmes, or entail taking on more staff on a temporary basis. The three firms, who are members of research associations which cater for a limited amount of sponsored research, supported the idea of a national institution for three different reasons. One of these said that it would tend to break the monopoly which some research associations held in their own particular industry, and provide a certain amount of competition, which would be a stimulating influence. This firm, although appreciative of the excellent work of the research associations in general, believed that the particular association to which it belonged lacked that drive and sense of urgency which a little healthy rivalry with an institute for sponsored research could supply. The second firm had found it difficult to persuade its own association to undertake a particular research project, and said that if a sponsored research institute were in existence such a difficulty would not arise. The third firm was of the opinion that the research associations were handicapped by lack of money to undertake large sponsored research projects, a weakness which would be less likely to hamper an institute specially designed to meet such needs.

Trade Associations and Similar Organizations

Another source of scientific and technological information is provided by the trade associations and their investigation sections. It is rare for the trade associations to undertake scientific research themselves, but they do provide financial support to other organizations which are actually engaged in research, and so act as a channel through which the results of

research reach industry. There are other bodies similar to trade associations which exist for the promotion of the use of certain products and these, too, to a certain degree, serve their industries' scientific needs through their information and technical service sections. The Institute of Brewing, for instance, was reported by four breweries as having given them invaluable help, both in development and in connection with day-to-day problems. (This institute, incidentally, has recently set up its own research organization.) The Copper, Tin and Zinc Development Associations provided assistance to four firms, while other organizations mentioned as having been of service were the Paper Makers' Association, the Federation of Engravers, the Timber Development Association, the British Rubber Producers' Association, the British Lubricating Oil and Grease Research Association, and the Trade Association of the Soft Drinks Industry. A special privilege available to iron foundries by virtue of an arrangement between the British Cast Iron Research Association and the Joint Iron Council was brought to the investigators' notice. By this agreement every firm engaged in the iron-founding industry throughout the United Kingdom is entitled to membership of the Research Association by the simple formality of completing a form of application, and only one of the foundries visited had omitted to take advantage of this offer. Attention is drawn to this particular arrangement as an example of one way in which a trade organization has taken action to provide its industry with the scientific knowledge it requires, and similar arrangements, though differing in detail, apply in a few other cases.

In the course of the survey, two firms were visited which, in addition to membership of the appropriate research association, also belonged to a private research organization controlled and financed by seven firms which specialized in the same, very narrow field. This organization—additional to the research and development sections of the individual firms—had been set up both to investigate fundamental problems and to undertake development work of interest to all the members. The

advantage claimed for this system was that it prevented duplication of long-term fundamental research and at the same time left each firm complete freedom to pursue its own development projects in its own way. *Ad hoc* problems could also be submitted to the organization and thus ease the strain on the laboratory staffs of the member firms. The Director is allowed considerable latitude in the work which is undertaken and reports at intervals to the governing council elected by the member firms. The organization has its own library and issues to its members at regular intervals a bulletin giving details of the work done and containing pertinent abstracts from the technical and scientific press.

Consultants

The use of technical consultants is fairly well spread over all four industry groups, with the possible exception of the textile group in which only 16 per cent. of the firms avail themselves of this service compared with an average of 27 per cent. for all four groups put together. The practice of resorting to technical consultants was encountered irrespective of the size of the firm, except for a decrease in the case of those employing fewer than 100 persons.

The use of consultant specialists for particular subjects is a long-established industrial practice, and one which has been exploited by all types and sizes of firms. For the purpose of the present survey, information has been collected not only regarding the extent to which scientific and technological consultants are used, but also on the employment of consultants in business management and administration, time and motion study, and building construction and design. Although these latter consultants do not directly contribute to the flow of scientific knowledge to an industry, they have been included because they can help a firm to achieve a condition that is better able to absorb the scientific and technological information that is needed.

Scientific and technological consultants were found to be

employed in many ways and for many purposes. Some are paid a retaining fee and so come to occupy a position which can be compared with a part-time member of the staff. They are always available for consultation, and in many cases take an active part in the preliminary discussions preceding a decision on research, development or production policy. Perhaps the most significant feature which emerged so far as the employment of permanent consultants is concerned, is that there are two distinct aspects of such service. There is, in the first place, the consultant who is retained to act as specialist adviser to a firm already well equipped with scientific and technological staff and which undertakes research and development of a high order, and, secondly, the consultant who is employed to advise on day-to-day problems beyond the capacity of the firm's own personnel. An example of the latter is provided by a small firm in the electrical accessories trade. It has no qualified chemist though it is engaged in a section of the industry in which chemistry plays a subsidiary part. Rather than engage a full-time, qualified man to supervise this aspect of its business, it relies on the services of a permanent chemical consultant on whom it can call for assistance at any time.

There was a clear line of demarcation between these two groups, not only as regards the services required, but also the sources from which such consultants were obtained. Firms requiring advice on subsidiary, day-to-day problems, relied on consultants who were in business as such, whilst those occupied in research on their own account preferred to retain the highest authorities available. Apart from the firms which retain permanent consultants, a number call for similar assistance when some special problem arises on which external advice would be especially helpful.

Sixty-one firms in all were in the habit of making use of scientific and technological consultants for one purpose or another, and over half of these sought help in connection with their research or development. The remainder sought scientific information or advice on day-to-day problems, including

a small number which required analytical or other examination of their raw materials or products.

There were no outstanding examples of either praise or criticism. In the majority of cases it was considered that the service provided by consultants in the Manchester area was satisfactory and adequate for industry's needs, and no suggestion was made that any firm using consultants had fears that its secrets might be revealed.

Consultants on business administration or on time and motion study were not used to the same extent as those on scientific or technological questions, but nevertheless played their part in the general policy of certain firms anxious to keep their process and office administration up to date. Firms in the textile industry in particular were found to have paid considerable attention to the redeployment of both labour and machines, in which they had been greatly assisted by time and motion study consultants, and in every case save one, these firms were satisfied that they had benefited materially from the advice received.

Architects, consultants on building construction and heating and ventilating experts were employed by 10 per cent. of the firms and were generally said to have given excellent service.

Suppliers of Raw Materials or Plant ; Customers

The extent to which the suppliers of raw materials or of plant are looked to by the firms for assistance in connection with their scientific and technological needs is outstanding. This source, more than any other, is responsible for providing the scientific background and advisory service to over 40 per cent. of the firms encountered, and is of particular importance to the small firm with very modest scientific or technological pretensions.

One of the chief concerns of any manufacturer is to satisfy his customer, and one way in which he can help to ensure this is by seeing that his products are used in the right way and to the best advantage. For this purpose he has in many

cases built up a technical sales organization, staffed with well-qualified men who understand not only the chemical and physical characteristics of the products they have to sell, but also those products used by other industries. They are, therefore, well able to provide helpful advice to users on methods of application and on the means of overcoming technical difficulties, and have at their disposal the whole of the scientific resources of the supplier firm. It is not surprising, therefore, that so many firms rely on their suppliers for scientific and technological advice not only with regard to questions affecting that supplier's particular product, although this is naturally the main subject, but frequently on matters far outside such fields.

It was found, for instance, in the textile industry, that considerable reliance was placed on those firms which supplied dyes or synthetic fibres, the dyestuff suppliers being invariably consulted by the smaller firms when a certain effect was required in the finished, dyed material. Firms introducing for the first time synthetic fibres into their process were faced with the solution of new problems necessitating changes in technique, and those in the spinning, weaving and finishing sections of the industry invariably consulted the suppliers of the fibre, and worked in conjunction with them to perfect the final product. Suppliers of paints, enamels, rubber chemicals and moulding powders, give similar excellent service to their customers in the manufacture of electrical accessories or in the rubber industry. Engineering firms were similarly helped in their particular field by the suppliers of the metals and alloys they used.

Plant manufacturers were consulted by firms in all industries when it came to installing new plant or replacing plant which had become worn out or out of date. They were frequently asked for advice and assistance if a firm wished to introduce modification of, or innovation in its own design ; they also gave advice, if a customer wished to introduce a new product, on the best means of achieving his object.

In these and similar cases, there was a close collaboration

between supplier and customer, and several plant manufacturers remarked that most of their customers were willing to try out prototype machines on a works' scale and under industrial conditions, and that without this ready co-operation from the customer, their development of new plant and machinery would be badly handicapped. Another way in which the customer was of assistance to manufacturers was in suggesting new, or modified lines of production, and then, in conjunction with the producer, in helping in the design and method of production. This was especially manifest in the weaving and finishing sides of the textile industry; the customer, in most cases the merchant-converter, furnished ideas or objectives, and the weaver or finisher developed techniques to achieve the desired result.

From what has been said, it may be concluded that there is a high degree of co-operation between supplier and customer, each helping the other in his developments and daily problems. The supplier is ready and willing to do all in his power to see that his goods are used in the proper manner and, in return, the customer assists the supplier by suggesting new materials or in trying out new products or prototypes on a works' scale. Several notable examples were encountered of such co-operation between the National Coal Board and the British Electricity Authority on the one hand, and manufacturers of equipment on the other. The former bodies first specified their requirements and then worked in close co-operation with the supplier's research and development organizations, to the mutual advantage of both sides.

Associated Firms in the United Kingdom or Abroad; Friendly Firms in the Same Industry

A number of the firms, although separate entities, were closely associated with others, either as members of a combine, or as offshoots of a parent company, and in all these cases a free exchange of scientific and technological information was common practice. Sometimes each member of the group had

its own research and development organization, whilst in other cases there was a central research section which worked for all the members and attended to their scientific and technological needs. Some firms were associated with foreign companies in one or other of these ways, and whilst having their own research or development departments in this country, also benefited by the work done by their associates abroad. Other firms in this category relied solely on the services of the foreign parent company or associate, and any development carried out in this country amounted merely to the adaptation to British conditions and standards of the results of research done elsewhere.

A similar state of affairs exists in those firms which are closely linked, as subsidiaries or associated companies, in this country. In some instances they relied entirely on the parent company to provide research and development facilities, and the incorporation of the results of such work into the firm's production programme was decided solely by the parent concern. Others had their own research and development organizations and exercised considerable latitude, not only in the nature of the investigations carried out, but also in the incorporation of the results of such work into their production programmes.

A case in point is a large firm in the group of miscellaneous industries which is part of a combine. The latter has a technical liaison director who attends the monthly research meetings of all firms in the group, at which meetings the research, development, technical and sales managers are present. In this way not only are the problems which have arisen debated within the firm itself, but the presence of the technical liaison director ensures that work being done in allied establishments is disseminated and the danger of duplication of effort minimized. The research department is given a general directive by the board of management through the technical liaison director as to priority, but is otherwise free to decide and plan its own work.

Another type of association is seen in the friendly co-operation

between firms in the same trade but not associated with each other in any other way. This varies considerably from industry to industry, but in some industries cases were found where such co-operation and help was freely given by one firm to another, even to the extent of a temporary exchange of staff. In others, the doors were kept shut fast and an air of secrecy pervaded the whole works.

This spirit of co-operation was most evident among the smaller firms in the textile industry and in the ferrous and non-ferrous foundries, but other cases, on a smaller scale, were encountered in the fields of general engineering and electrical accessories. Whilst this type of co-operation is by no means general, the investigators were informed by many establishments that very definite progress has been made since the war. Whereas prior to 1939 most firms discouraged an exchange of visits and discussions on production methods or processes, this attitude is slowly disappearing and an atmosphere more conducive to mutual help is taking its place.

Scientific and Technological Societies and Institutions

No evidence of the scientific and technological institutions or societies exerting a direct impact on industrial progress came to light during the survey. Although relatively few of the firms were corporate members of such bodies, a large number had members of such societies and institutions on their staffs, and gave encouragement to these members to attend meetings both in their spare time and during working hours. A few firms went so far as to pay the subscriptions for their staffs, whilst others, although not doing this, paid their travelling expenses in attending meetings.

There can be little doubt that considerable use is made of the publications of the societies, on which subject something is said in the section dealing with libraries, but no specific case was found in which these societies or institutions had a direct influence on the firm's activities, except in two cases

where application was made to the Royal Institute of Chemistry when chemical staff was needed. The societies and institutions which are included in this section are those which are genuinely scientific or technological in nature, and which hold meetings at which papers are read and discussed and subsequently published by the society. Ordinary trade federations and associations are, therefore, not included, nor are those local sections or societies at the meetings of which information of considerable value may not infrequently be exchanged. There seems little to be gained by recording the memberships of individual bodies, and it will be sufficient for the purpose of this Report if a simple statement is made giving a summary of the general position as disclosed by the survey.

MEMBERSHIP OF SCIENTIFIC AND TECHNOLOGICAL SOCIETIES AND INSTITUTIONS

	Number	Percentage
Number of firms who are corporate members	18	8
Number of firms who are corporate members and where staff are members as individuals	26	11
Number of firms where staff only are members	98	44
Number of firms with no membership connections of any kind	83	37
Total	225	100

LIBRARIES AND PUBLICATIONS

During the course of the investigation, inquiries were made as to the extent to which firms possess scientific and technological library facilities of their own and the use they make of external libraries which they consult when their own resources are insufficient. Another matter which is closely linked with this is the question as to what use is made of the vast number of scientific, technological and technical journals which are published. How many firms study these systematically and abstract for present or future use the articles, papers or references which relate to their interests? How many firms

merely scan the periodicals casually before throwing them into a corner, never to be looked at again? All these factors can play an important part in a firm's efforts to keep up to date and *au fait* with the latest advances in science and its application.

It did not seem feasible to try to evaluate the libraries possessed by the firms merely by putting them into categories such as large or small, good or bad, as this could only be an assessment and, as such, open to criticism. Instead, they have been divided into four classes based on the degree of supervision, as this will, it is believed, give a more satisfactory picture not only of the number of firms possessing libraries, but of the degree of importance attached to them and the extent to which they form an integral part of the firm's activities.

ANALYSIS OF THE 96 FIRMS REPORTING THE EXISTENCE OF A LIBRARY OF THEIR OWN

	Number
Number of firms with library and trained librarian	11
Number of firms with library and full-time staff but not a trained librarian	6
Number of firms with library and part-time staff	58
Number of firms with library without proper supervision	21
Total	96

All these libraries were stocked with textbooks, industrial handbooks and reference books pertaining to the particular industry. In most cases provision was made for buying new volumes and the latest editions of previously published books, and one firm did not limit the contents of its library merely to books of a scientific or industrial nature, but included certain novels and other books for their thought-provoking or character-building qualities!

Every firm, without exception, reported that it received scientific, technological or technical journals, but it was found that the use made of these periodicals varied widely. Just

over 50 per cent. of the firms had a systematic method of circulating to the staff all the journals received, and of this number, half had an abstracting service which indexed and filed for reference those papers or articles connected with the firm's business. In some of the smaller firms, and in those where there were only one or two technological staff, and these at board or managerial level, it was usual for the technical director or manager to study the journals and make himself personally responsible for keeping up to date with developments in his industry. Others said they were too busy to follow this practice and could only afford time for a quick glance through the headlines in the hope that they would be fortunate enough to spot any new development. In a number of firms there seemed to be no recognized routine for dealing with incoming publications. They were treated in a most casual manner and it was assumed that the staff knew that they were in the office somewhere and would make inquiries should they at any time wish to study them. A rough-and-ready approximation suggests that in some 60 per cent. of the firms there was someone who studied all the incoming journals fairly thoroughly, but that in the remainder the attention paid to them was extremely casual.

Although a factual picture has been obtained of the extent to which libraries are maintained, and of the ways in which incoming journals are treated, it is not possible really to assess what benefits the firms derive from these sources in the normal course of their operations, or whether they derive any new ideas from this source. All that can be said is that the facilities are available and that the use to which they are put depends entirely on the firm itself and its personnel. In the case of firms using external libraries, however, more positive action is required and the position is a little clearer. A visit to an external library, or the request for service from such an institution, will only be made with some definite end in view, and a study of those firms which made use of these external facilities will shed light on the value of libraries in general.

A full analysis of firms making use of external libraries will

be found in the tables in Appendix 1, and here it will suffice to summarize the position by saying that just over half of the firms visited are in the habit of consulting external libraries from time to time. The remainder, although aware of this source of information, said that they had no occasion to use it.

As would be expected, the libraries most frequently used are the Manchester Central Library and the libraries of the University of Manchester and College of Technology. No less than 58 firms referred to the Manchester Central Library and used not only the books and periodicals but also the experience of the library staff who frequently advise their clients as to the latest or most suitable volume to consult on any particular problem. One firm said that a monthly routine visit was paid to this library to see what new technical books were available and to study those periodicals to which they did not themselves subscribe with a view to purchasing for their own library any which contained items of direct interest.

At both the University and the College of Technology, frequent use is made of the libraries by those firms having contacts with these bodies. The libraries of the research associations, particularly that of the Shirley Institute, were consulted in many cases and, apart from the usual consultations with these associations, a number of firms specifically mentioned the considerable benefit they derived from the lending facilities of these libraries. Other libraries used included those of the learned societies, the four big engineering institutions, the Iron and Steel Institute and the Institute of Metals, the Textile Institute, H. K. Lewis's Library (Gower Street), and local technical libraries situated in the towns around Manchester. It was not found that A.S.L.I.B. (The Association of Scientific Libraries and Information Bureaux) was very widely used, its functions being, in fact, in many cases unknown until they had been explained by the investigators. Twelve firms, however, said that they had been well satisfied as a result of their contacts with A.S.L.I.B., and several others, after learning the nature of its activities, asked

for pamphlets published by that organization with a view to getting into contact.

Publication of Work Done in Firms

There is one other means by which scientific knowledge can be disseminated, i.e. the publication by a firm of the results of its own research.

If the work is of a truly scientific character, it may be published by communication to one of the learned societies or to a journal such as *Nature*. If, on the other hand, it is of a technological character, but at the same time strikes new ground, it may be communicated to one of the professional institutions or published in a technological journal. Each firm was asked what was its policy regarding publication of the results of its own research and development work. In most cases it was found that nothing was done apart from sales propaganda or articles to the trade press likely to suit the taste of potential customers. Eight firms said that publication was not encouraged for reasons of secrecy, and many others stressed the fact that no work was carried out by the firm which justified publication. On the other hand, 7 firms, all in the modern group of industries, encouraged publication of the results of research of a fundamental nature, and 25 made some of the results of their technological work known through the medium of the professional institutions or the technical press. A further 26 firms said that they occasionally wrote articles for the popular technical press likely to be of interest to the general industrial public.

These were the only examples encountered and it seems clear that, in general, publication is restricted to advertising and sales propaganda rather than the increase of knowledge.

In conclusion it may be mentioned that 44 firms gave concrete examples of problems of a scientific or technological nature which were giving them trouble and to which they had so far been unable to obtain an answer. In most cases the problem could have been solved quite quickly had the firm

known whom to approach for assistance. Indeed, on several occasions, as a result of the interview between the firm and the investigating officer, the Manchester Joint Research Council was able to put the inquirer in touch with the most appropriate source of information.

The investigators themselves feel that there is such a wealth of knowledge and experience to be tapped merely for the asking, provided that industry is aware of the particular quarter to which its queries and problems should be directed, that it is difficult to believe that a lack of scientific or technological advice should ever be a stumbling-block in the path of industrial research or development. But clearly there is a very real need of some means of informing those in industry where the most appropriate sources of knowledge are to be found.

Tables 36–45.

CHAPTER VII

SOME MISCELLANEOUS OBSERVATIONS

The sudden death after a short illness in the spring of 1953 of the chief investigator, Mr. A. D. Butchart, and the departure of the two other members of the investigating team on the completion of their share of the joint work some weeks earlier, resulted in the completion of this Report falling to other hands. Among the memoranda, some only partly completed, left by the investigators, were a number of reflections on matters which had arisen during the course of their labours, and of these, six were deemed pertinent to the general scope of the survey. These memoranda are essentially as they were left by Mr. Butchart ; there is no particular sequence, and it is for the individual reader to decide where, for his own purposes, they enter into the general argument.

Personality as a Dominant Factor in Industry

The investigators were deeply impressed with the overwhelming importance of the personality of the chief executive in the firm, whether he went by the title of chairman, managing director or general manager.

In industry, authority and its accompanying responsibility come to men by diverse and, at times, apparently accidental routes, but what is almost always true is that when top-ranking status does come to a man he is virtually supreme within the firm. So far as concerns the subject of this inquiry, it is certain that it is the outlook of the chief executives of industry which is the governing factor in determining how widely, and wisely, the resources of science will be employed to stimulate progress and efficiency. There are many industrial leaders whose thinking on this subject is dynamic, progressive and extremely well-informed, but it seems equally true that there are others of whom that cannot be said.

There is, therefore, much more to be done, if full cross-fertilization of science and industry is really to lead to the greatest possible enhancement of Britain's industrial efficiency, than merely to train more scientists or to establish more and larger research institutions. A " climate of opinion " must be extended in industrial circles so that it will become instinctive with *all* members of the industrial community to look to the help that the resources of science can provide with both hope and faith, no matter what effort this may entail, nor what patience may be required. Much has been done in recent years to foster such an attitude of mind. This is proved by the number of cases encountered by the investigators of some definite action initiated by firms within the past ten years, which clearly has arisen from an impulse to rely on science more than hitherto. If the taking of at least one decision, which can reasonably be held to imply such a tendency, is a measure of this change of attitude, it may not be without interest to record that, after reviewing the notes of all their visits, the investigators report that $12\frac{1}{2}$ per cent. of the firms visited have within the past ten years acted on a decision of that kind in a really substantial way. This is inevitably a rough-and-ready generalization, but it is probably reasonably accurate as a measure of the progress made in the task of fostering " science-mindedness " in industry as a whole.

Science-mindedness

The investigators believe that of the firms in which a scientifically trained staff was necessary, 42 per cent. were understaffed and of these one-third, mostly small in size, showed no realization of the fact.

While it is not intended to suggest that none of the firms classed as reasonably staffed could not usefully employ still more scientists or technologists, it is true to say that they are, where necessary, endeavouring to increase their strength and thus widen their activities.

There are varying degrees of science-mindedness in indus-

trialists. Though some consider that a works' testing laboratory is essential, they see no need for more. Others seek trained men for their production and management, while still others appreciate the value of research and development. The most impressive cases which the investigators encountered were very often those in which, somewhere high up in the firm, was a man with close personal friendships in university circles. Industrialists who mix with scientists on such a level have an attitude not normally found—a strong argument in favour of deliberate action to multiply the opportunities for further contacts between the worlds of industry and science.

The investigators were impressed at an early stage with the fact that there is a form of science-mindedness in industry which depends hardly at all upon research, if by the word "research" is meant a deliberate and organized search for new knowledge. There already exists a tremendous fund of scientific information which is capable of being readily understood by individuals making little claim to an academic background and whose technical training is limited to what has been picked up in the course of their industrial career. It is possible then to show resource in utilizing such knowledge in the improvement of industrial processes without being a scientist in the formal sense of the word, and to make recommendations which are scientifically fairly simple, but which yet may make possible some quite striking improvement or economy. It is an obvious manifestation of science-mindedness in a firm if it is adept in grasping such ideas, from whatever source they may come, and applying them to its own purposes.

In some branches of industry a great deal of relevant scientific knowledge is quite freely available to all firms, either from their research association, suppliers or consumers. Where these conditions obtain, a firm need only fortify itself with personnel of quite modest scientific or technical attainments to be in a position to absorb and apply many benefits from this store of knowledge. It would be commercially extravagant for such firms to employ large scientific staffs, and if the number

of science graduates they employ is small, it does not necessarily imply that their performance is unworthy of commendation.

Differences in Methods of Applying Scientific Knowledge

It has been a matter of the greatest interest to the investigators to note what excellent results have been achieved from entirely different lines of approach. One firm visited, for example, which had established a research and development department within the past ten years, had formed the opinion that the personnel appointed to this department should be encouraged to form a little coterie of their own and to develop a spirit of service to all the other elements in the firm. In this case, the results had been of the happiest. The scientific team were happy and their output of work was excellent in quantity, well directed to the practical objects in view, and their relations with the production departments most cordial.

In another case a very different set-up was encountered which was apparently no less satisfactory. A highly qualified scientist, with much industrial experience, was given a seat on the board of a company where there had not previously been a great deal of contact with scientific method. The new director had a status which entitled him to make proposals affecting any part of the firm's activities. He found at first, as such a newcomer might expect to find, that there was a certain resistance to his intervention ; he still has to school himself to a certain patience, but his seniors in the firm declare that the initial decision has been well justified.

In a third case a firm which had built up a great business on the strength of the inventiveness of the founder and his successors, considered that they should perhaps now depend on a more formal scientific basis and that mere inventiveness would hardly suffice to retain leadership in the world of to-day. On this reasoning, for which there seemed a great deal to be said, a highly qualified academic scientist was engaged to build up a research department. Whatever the reason may

have been, and the investigators would be hesitant to attempt a diagnosis, the arrangement broke down and was discontinued. One of those concerned, who seemed himself to have a very objective point of view, thought that the root cause of the breakdown was that the scientist had no idea what industry required from him, whilst the industrialist was equally at sea regarding what he wanted from the scientist.

These three examples, two of success and the third of failure, illustrate how much depends upon the personalities of the principal actors. In each of the cases referred to, it is clear that the eventual result was largely determined by the personalities involved. It may be doubted whether there is any moral to be drawn from such variations of experience, except that systems are probably less important than personalities, and that knowledge, without a certain flair for living and working with other people, is likely to be less effective in the industrial world than in the academic.

Communications between Science and Industry

Another matter which emerged strongly throughout the whole investigation concerned the inter-communications between the worlds of industry and science. Executives in industry to-day are hard-pressed, and even when trained as young men to read systematically, they rarely now have the time to do so. Their day-to-day work necessitates a great deal of duty reading, much of it to keep them informed on markets, trade regulations and policies, and general events, with all of which they must be familiar in order to take even the minor decisions inseparable from their responsibilities. In consequence it is difficult to reach them effectively by the printed word. They would certainly read with care and receptiveness anything bearing directly on their business, but when they look at research association bulletins, or pamphlets from other scientific sources, they often find so much which does not apply to them, that they do not delve deeply enough to uncover something which might be of more indirect concern.

It must be admitted that it often requires a special imaginative effort for executives to perceive the possible relevance of much published material to their own problems. Whatever the reason, it is certain from the results of this investigation that heads of businesses do not in general get much from the printed word in its existing, conventional forms. Many of those interviewed seemed more than glad to have the opportunity of dealing with the matter orally, and the inference may well be drawn by all who are concerned with the relationships of science and industry, that opinion is more likely to be influenced by the arduous process of individual conversation than by any other form of activity.

In many circles the prevailing level of interest in research and development work is not very high, nor is it based on a thorough grasp of the way this particular factor in industrial progress should be handled. There seems to be scope for much propaganda in managerial circles—using the word propaganda in its very best sense—to bring a more vivid impression of what is being achieved in other industries, or even by competitors in their own industry, to the knowledge of those who have not themselves thought deeply on the proper functions within a firm of its research and development activities.

It was clear to the investigators that very little of positive value results from an occasional speech on the subject of research and development techniques by some prominent man, or from the circulation, at rare intervals, of some exposition of this theme by a scientist or a research organization. The subject has got to be ventilated persistently from every conceivable angle, and perhaps nothing would prove in practice to be more influential than the publication of "success stories." Fortunately, as is remarked elsewhere in this Report, the modern industrialist is much less secretive than his predecessors used to be. He realizes that he is part of a community and that the success of that community is one of the factors in his own prosperity. When he makes generally available details of his own methods which have yielded good results, he will often receive in exchange other information

which may enable him to make still further progress. In such an atmosphere there is a growing readiness to permit visits to factories and to allow information to be made public.

Science and Plant Efficiency

It would seem that the majority of firms regard the scientist/technologist as of value primarily in the fields of research and development, and there are relatively few employed solely for process control and testing. Their value in research and development is unquestioned, but the investigators have a strong impression that too little attention is being given to the service which such men can render in maintaining, or improving, the efficiency of plant and process. This is true not only of those firms at present without any qualified staff which might well find a scientifically trained man of real value for this purpose, but also applies in other cases where scientists/technologists are employed only in the laboratory. Too frequently in the production sections of firms with no qualified men in control, nobody questions the general assumption that the work of the laboratory is concerned solely with a certain scientific routine, and cannot be expected to assist the technicians and engineers in the solution of their day-to-day problems.

There is a story of a firm which was operating in a recently scheduled smokeless zone which, having adjusted the supply of air to its boiler furnaces until no smoke was emitted from the stack, then doubled it to make sure that they were on the safe side, and were surprised to find that their fuel consumption rose sharply ! Although the investigators did not come across a case quite in this category they did hear of several instances where, for example, a firm had never worried to determine the efficiencies of their boilers, turbo-generators, heat exchange equipment and so on in spite of the fact that qualified personnel were employed in other sections of the works who were fully capable of carrying out the simple tests and analyses required. One boiler plant was visited which, while spotlessly clean, and

to all outward appearances in good shape and well instrumented, was being operated without any knowledge of how to make use of the results recorded by the instruments. An examination of the records revealed that for some weeks the boilers had, if the instrument readings were true, operated at well over 100 per cent. efficiency. No attempt, however, had been made to check the accuracy of the data as the operator had no idea how to calculate the efficiency of the operation, and, therefore, did not realize that anything was wrong. The position was made worse by the fact that this firm had qualified men on the staff, but, owing to the system of watertight compartments which was encouraged by the management, they had not been called into consultation.

At another firm it was learned that, although at present there was no qualified person on the staff, the son of one of the management was working for a degree at a university, and would then do one or two years' post-graduate research before joining the firm to undertake its research work. To the investigators it seemed that the firm was far more in need of a qualified man to supervise production and to control efficiency than someone to specialize in research.

The investigators feel that there is ample evidence that industry is aware of the need for scientists and technologists in the research and development sides of its business and makes considerable use of them for this purpose, but that the value to be obtained from them in actual production is much less adequately recognized. It may well be the case that in industry as a whole the greatest immediate benefit from science would be reaped by paying much more attention to this aspect of the subject.

What Kind of Science Graduate should go into Industry?

Some people have argued that the scientist trained for research work often lacks a flair for business management. Whatever be the truth of this, it is a striking fact that during

this investigation no instance was encountered of a director who had reached board level direct from a research department. Some there were who had originally been in the research department, but they had attained the status of director by way of development or works' management. This parting of the ways normally comes fairly early in the life of the industrial scientist, and it is highly probable that the seniors in research departments are men with a flair for, and a desire to continue such work rather than to move over to production or management.

In very few firms is there much opportunity for a man to engage in fundamental or long-term research ; most of it is of a short-term or *ad hoc* character with a definite bearing on some particular industrial problem. This at once would suggest that a man with a good degree and a definite preference for pure science should not enter industry unless as a member of a very large firm which does encourage fundamental research. His true home is more likely to be found in the universities, research associations, government research stations, or in that section of industry where real research does go on, and where his work would be more in keeping with his interests as he then conceives them.

It is clear, however, that there is ample scope in industry for men of scientific training in the direction and control of production, and in the application of scientific information—whether new or already well known—to the improvement of products and processes. For this kind of work, the " research " man is not always fitted since it frequently calls for what is to him a rather humdrum practical training, and leads to a butterfly existence in which a problem is put on one side as soon as a solution sufficient for practical purposes has been reached.

Several industrialists have suggested that graduates who are considering a life in industry should, before leaving the university, be given a course in industrial administration which would, in their opinion, increase their efficiency and broaden their outlook.

Others have drawn attention to the lack of engineering training and knowledge, remarking that a development man in any section of industry, and any plant manager or controller, must have a reasonably good grasp of engineering principles if he is to be really efficient. Several have remarked on the fact that in other countries this grounding in engineering is given to all graduates in the sciences, and it was often stated that British chemists, physicists, etc., were trained almost solely for research or tutorial purposes, whereas in other countries the emphasis lay, to some extent at least, on training for industry. Whatever germ of truth there may be in this criticism, the facts collected in this Report prove that industry in this area does find it profitable to employ graduates in large numbers (4·7 per 1,000 employees). Further the figures for the number of graduates on the boards of directors is incompatible with the sweeping statements sometimes made.

CHAPTER VIII

GENERAL REVIEW OF THE INVESTIGATION

It is not particularly difficult to collect and record a large number of facts provided by well-disposed informants responding to precise questions. Nor is there anything hard in the task of noting arresting or unusual things which emerge in the course of a visit to an industrial undertaking, when the visitor is himself intensely interested, and widely experienced, in industrial practice. To review the facts and ideas thus assembled, however, is much more difficult. How far is it wise to go in offering suggested interpretations of the facts or of the deductions to be drawn from them, when it is manifest that everything is vitally affected by the particular circumstances of each individual case? How far will it be desirable to comment on facts already recorded, or will the reader whom it is desired to interest and serve be better left to digest the facts for himself and to draw his own conclusions?

These and similar problems were a source of much anxiety to the Steering Committee in the final stages of the investigation. Mr. Butchart's death and the earlier resignation of the two other members of the team removed the persons best qualified to give advice; those, too, who had been in most direct contact with the whole of the work. A draft of the Report was, however, in existence, though in a form hardly suitable for publication, and on this draft, and other memoranda left behind, this chapter is based.

Upon consideration it has been thought best to pass the various aspects of the investigation in brief review, and then to make some tentative observations regarding the conclusions which may possibly be drawn. These are clearly subject to the general reservation that it is impossible, when dealing with so complicated a subject, to reach finality in any single inquiry. The geographical area surveyed may have given

results differing substantially from those which might be obtained from a corresponding investigation carried out elsewhere, and the limitations deliberately imposed on the investigation, and discussed at length in Chapter I, cannot but have had some effect. Everyone connected with the survey has appreciated, from its very inception, that the most that could be hoped for would be that it would make some contribution towards the elucidation of a subject of the greatest importance to the national well-being, but equally of the highest complexity.

To begin this review, attention is first redirected to the first chapter where it was made clear that the objective of the inquiry was the impartial collection of facts bearing on the reasons usually given why Britain lags behind other countries —if so it does—in absorbing new scientific and technical knowledge into industry. It was not intended to try to decide whether the criticism was justified, but simply to collect the pertinent data.

The information collected about the employment of scientists and technologists in industry, discussed in Chapter II, sheds some new light on the question. What stands out particularly clearly is the absence of any uniform pattern. Half the firms employed at least one qualified scientist or technologist, and these firms, between them, represented no less than 84 per cent. of the total employed personnel covered by the investigation. About five-sixths of all the scientists and technologists employed were concentrated, however, in just under one-third of the firms, these being concerns which, by reason of the nature of their business, or because of a deliberately adopted policy, are really active in research and/or development. At the other end of the scale, there was a group of firms, again about one-third of all those visited, which employed few or no scientists or technologists, and which were engaged in work of a type such that science had little or nothing new to offer regarding either their processes or materials.

The data collected seem to establish fairly solid grounds for believing that the degree to which industry makes good use

of science—good that is to say in relation to the maximum possibilities for scientific help in that particular kind of industrial activity—is the direct consequence of the outlook of the top management in each particular firm. In some industries no matter what this attitude may be, scientific knowledge is indispensable—though even in those cases there can be a better or worse deployment of the scientists employed—whilst in others there is no compelling necessity to resort to the services which those with a scientific training can give. Judged by the picture as revealed by the investigation, there is no evidence that scientists are, to any material extent, wastefully employed. There are some signs of certain difficulties in the recruitment of a fully adequate supply of scientists for industry, which would become still more acute if the demand increased further. It is a matter of opinion, however, whether there is real justification for the belief that a shortage of scientists is the basic cause of whatever faults there may be in the present situation. The strongest impression of all is that the position is in reality dominated by the attitudes of those at the top management level. Such changes as have come about in the last decade or two are the result of a changed " climate " of thinking in the highest management circles, and when executives have been convinced about the merit of a certain course of action, they do not seem to have found any of the difficulties in the fulfilment of their aims insuperable. Many have done so much and so well that there seems no reason to doubt that others, if equally determined, could equal their achievements.

What emerges most strikingly from the study of the research and development activities of the firms is the great difference which exists between various industries. If the investigation has done nothing else it has surely demonstrated that generalizations covering the whole field of British industry regarding the use which is, or should be, made of scientists and technologists may be wholly unjustified. Circumstances vary so tremendously between the different trades that arguments based on the conditions prevailing in one are little or no guide to sound conclusions in another field.

The investigators were often asked by industrialists if they could offer a definition of what might be regarded as a satisfactory criterion of the proper use which should be made of science by industry. As they passed from one industry to another, or even from one establishment to another, they themselves became more and more convinced that it would be quite irrational to attempt to apply any common standard to all industrial concerns. Even when two or more firms in similar fields of industry, and of approximately the same size, were under consideration, there were still special factors, of finance or of market outlets, which often rendered a valid comparison between the two difficult in the extreme.

One of the outstanding things to be observed is that in general, scientific enterprise in industry neither does, nor necessarily should, mean a seeking after knowledge for its own sake. It may equally well mean a search for the means of applying to the problems of an industry, or of a particular industrial undertaking, items of existing scientific knowledge whereby a product may be improved without changing its essential character, or the same product may be manufactured more economically. Indeed, it might well be argued that it is not really the business of industry to engage in fundamental research for the mere enlargement of the frontiers of knowledge, so much as to carry out such research as will conduce to the application to the functions of industry of those stores of knowledge which are already available. When it is found, therefore, as the investigators have in fact found, that very few firms—and these in the main only the largest undertakings—do spend money on research, having for its primary objective the discovery of new fundamental knowledge, it is not to be inferred that industry as a whole is in any way failing in its duty.

As matters stand in Great Britain, a great deal of the highest scientific work is done at the universities, and in research establishments totally or partly supported by the State. Industry makes its contribution to these activities mainly through the medium of taxation, and influences their nature

and scope by means of the advisory committees which are part of the system. It is also true, however, that even in recent times when taxation has been so heavy, industry has still encouraged fundamental research at the universities by gifts and grants. It was, however, no part of the purpose of this investigation to consider the relative merits of State support and private benefactions, or of variations which may exist in other countries ; the object was the more modest one of inquiring into the *de facto* relationships of industry and science amongst the particular series of firms which have been consulted.

The facts collected regarding the co-operative research associations should be of interest to those responsible for the direction of the Department of Scientific and Industrial Research, to whose encouragement and support the existence of such research associations is due. The work of the survey, while emphasizing the great importance of the contribution of the research associations, reveals at the same time the limitations of the research association movement and of the part it can be expected to play in relation to the total problem of the use of science in our industries. The contribution of the research associations is indispensable and is rendered effectively. In some fields of industry it is the main channel for spreading the scientific outlook over the arena of industrial effort : it is providing what is, perhaps, available in no other country in like degree, namely, a substantial flow of both scientific and technological knowledge directly applicable to the particular branch of industry concerned. When all is said and done, however, the movement still only covers a part of the British industrial field and, even in that which is covered, the *application* of the results of this co-operative research by competitive units is a matter outside the hands of the research association, however satisfactory may be its liaison with its members. Once again, the final issue is seen to depend on the decisions of those in charge of each firm's activities.

Chapter V on the contacts between industry and the

universities may surprise many people led astray by the general talk either about the indifference of the British industrialist towards science, or the isolationism of the academic scientist. Allowing for the many branches of industry where the processes are simple and repetitive and which, therefore, have no obvious or pressing need for new scientific knowledge, the overall picture is of far more contacts between the universities and industry than might have been supposed to exist. No less than 40 per cent. of the firms visited make practical use of the contacts they enjoy with one or more universities. It is common knowledge that the number of students graduating in science in the post-war years has been much greater than ever before, and as those who have entered industry rise in the scale of influence and responsibility, the contacts between the universities and industry will grow both in number and importance.

It is to be hoped that Chapter VI, "Other Sources of Information," will receive the attention it deserves. It seems to be a fact that outside the field of the industries directly linked with, and dependent upon science, there is little realization of the many routes which the inquiring business man can explore if he wishes to ascertain whether science has anything to contribute to his own particular problems. The impression to be derived from inquiries on these points constitutes a further reinforcement of the view that the outstanding need is for greatly intensified liaison between those in industry and the organizations concerned with scientific research and its application.

It has been emphasized more than once that those responsible for this Report have never regarded it as more than a contribution, inevitably limited both in scope and relevance, to a wide and complex problem. At the most, it represents more data which should assist in further considerations of the subject. That being so, it is difficult to decide how to bring it to an end. Perhaps the best way to do so will be to acknowledge that those who have been most closely concerned with the investigation have been acutely aware throughout that

sooner or later a question would be put to them, who had caused so many questions to be put to others. It was clearly inevitable that they should be asked what they, themselves, considered that they had learned from all these inquiries. There was a strong temptation to evade this entanglement. It was not entirely unreasonable to argue that it would be better and wiser to let the facts as assembled speak for themselves, uninfluenced by any general conclusions drawn by those responsible for the investigation. On the other hand, it seemed a poor return for the interest and support which had been so freely accorded to the instigators to flinch from the final challenge of saying what, in fact, they really thought about it all. An attempt has, therefore, been made to present, in a few brief paragraphs, the reflections of the surviving members of the small group of men who have throughout been closest to the work.

It seems clear that in certain fields of British industry, the resources of science are most effectively enlisted to aid and support our industrial progress. The way of doing things in this country may differ from accepted methods elsewhere, but the results may certainly not be less effective. To name items in which British practice and methods have proved strikingly successful would be invidious, but perhaps it may be permissible to say that there are British comets in other fields besides aviation. In all discussion of the use which British industry makes of science, there should be no unwarrantable depreciation of our achievements, which could only result in the lowering of our national prestige and in discouraging the coming generation both of scientists and industrialists.

Secondly, because large sectors of our industry are engaged on processes of a simple repetitive nature, we have many businesses in which the basic ideas have come either from the originators of the process or from their customers. Many of these have had no need of extensive resort to modern science, and to criticize those in control on that account is unjustified. Like everybody else, these men are the product of their times and environments, and what is needed is to effect a steady

change of attitude, not by petulant criticism, but by sympathetic liaison and education. The investigators have found in industrialists to-day a very ready disposition to listen to information and advice, indeed, a real hunger for good advice. But the advice tendered must be related to practical facts as the industrialist sees them, and recommendations must be workable within the limits of balance sheets and profit and loss accounts, and workable, too, from the standpoint of the human relationships in the factory as well as in the board room. So often the comments of the critic and reformer overlook these facts, which in practice must govern the decisions and actions of the firm. The point to be particularly noted is that at times the readiness to listen exists more widely than does something worth listening to in terms likely to be of practical value. In short, what aid science can bring to many branches of industry has not yet been expounded adequately from a standpoint calculated to convince the ordinary business man.

Liaison and suggestion are of course part of the programme of every agency now concerned with the application of science to industry, but what has struck the investigators is the inadequate penetration so far achieved. One of the clearest convictions this inquiry has left with those most intimately concerned is that more and better liaison and education are needed to a far greater degree than more and better science. The resources of science still untapped by industry are immense, and more and better bridges between industry and science, and greater mutual respect between the two worlds, are the prime needs in Britain which the investigators think their inquiries have revealed.

The most difficult questions to answer are those concerned with the supply of scientists for work in industry, and here the evidence gathered is far from clear. The trouble is the familiar one, whether to start with demand or with supply. It would be useless to increase supply, if the demand remained static : it would be frustrating to increase the demand if the supply remained inadequate. Probably, the painful truth is

that time is required—the desired results cannot be secured by a single act of policy at the top of the tree, either in the field of education or in that of industry. It is a case for pegging away with fine persistence from both ends simultaneously, and better liaison is also the best answer to this aspect of the problem.

Scientists know a lot about how life goes on in many branches of industry in which science already plays a powerful rôle : they know relatively little about other fields of industrial activity, which in total are very large. Business men in the first group of industries know scientists and the ways of science : in the second group, the business men concerned are as remote from the world of science as if they lived on a different planet. Here lies *the* problem for those concerned with liaison between the two fields of human endeavour. If the experience of the investigators is anything to go by, the printed word is likely to achieve little. Personal contacts are the only instruments to evoke an effective change in the habits of thought and the climate of opinion on both sides of the fence.

Some Final Observations

Bearing in mind the limitations of this survey dealt with at length in Chapter I, some of the major points which have emerged are outlined below.

The ultimate responsibility for the use of scientific knowledge, as for the introduction of any sort of new idea, lies with the board of directors and the top level of management of each firm. The personalities of such men, and their attitudes to the scientific approach to their production is, therefore, a matter of predominating importance.

There are many firms which, on account of the routine nature of their activities, or the extent to which they are controlled by the contracts to which they work, have little need of scientific knowledge.

Notwithstanding this, there are undoubtedly some sections of industry in which the most pressing need is for a

scientific approach to the normal operations of existing plant and machinery, i.e. for the control of process efficiency.

From the data collected, it cannot be doubted that there is a significant proportion of firms which by their activities require scientific help, but which are not so staffed as to be in a position to make use of it.

It also appears that many firms which could well use new scientific and technological knowledge have not the staff adequate to review the literature, to find out what is relevant, or even to appreciate the significance of relevant material when it is brought to their attention.

Although on this point mainly subjective, the evidence collected by the investigators is consistent with the view that where scientists/technologists are employed, they are not used wastefully.

Of the firms who were visited there was one section which had, or felt, no need of more qualified men, though whether they were in all cases justified in this view may be doubted. The remainder did feel the need of still more scientific staff, but had in some cases experienced difficulty in fully meeting it. If this demand were to be entirely satisfied, the present shortage of scientists/technologists, in certain subjects, might well become acute.

The information given justifies the belief that within their limitations the work of the research associations is well done, and generally appropriate to the industry concerned. Such associations even now do not cover the whole of the industrial field of the country, and with additional financial support might with advantage increase their technical contacts with their member firms.

The survey has revealed a much wider and closer contact with the universities than could have been generally expected.

Only a small proportion of the firms showed any genuine interest in sponsored research. These, however, fall into a sufficiently narrow range of industries to suggest that there might be room for an institution of this character to carry out work in the fields of chemical and electrical engineering.

The work of the investigators is over : the results of this survey are embodied in this volume, but the Manchester Joint Research Council is encouraged by the reflection that many beneficial results, which can never be recorded, have already arisen from the free and frank conversations between their investigators and some hundreds of business men in the area round Manchester. Across these modest bridges there has already passed a considerable traffic, and the best hope for the future of British industry lies in the ceaseless multiplication of this process.

APPENDIX 1

STATISTICAL TABLES

In the main body of this Report have been discussed the facts which have been determined in the course of the survey, and some conclusions drawn therefrom. In this appendix are given the details of the methods by which the sample was drawn, the data collected, and the manner in which the information was garnered and analysed. This more technical treatment may be of some interest to the general reader in enabling him to satisfy himself that the statements in the text are justified by the facts. To the statistician, or other research worker concerned with the problems under investigation, it is of value in that it will enable him to decide for himself how far the techniques used were appropriate to the object of the investigation, and to make comparison between his own methods of treatment and those here adopted.

Sampling and General Techniques

The field surveyed covers the region shown on the map, facing page 188, and was chosen as being representative of the Greater Manchester area. The Board of Trade Regional Research Office kindly furnished the breakdown, by Standard Industrial Classification and by size-groups, of all the establishments in this area employing ten or more persons. The figures so supplied are as at December 1950 and were used in preparing Table 1.

Since the names of firms could not be disclosed by the Board of Trade, recourse was made to trade directories, Chambers of Commerce membership lists and other similar sources, while for reasons already given in Chapter I it was decided to concentrate on manufacturing firms employing at least fifty persons, and on certain Orders. From this reduced population firms were drawn as described below. Table 1 shows that although there are 2,869 establishments employing between 10 and 49 workpeople, the total labour force of these is less than 70,000 persons, about 8 per cent. of the entire employment figure in the area for the Orders concerned.

It was clear that the different Industrial Orders were very differently represented in the area covered, the number of establishments ranging from 15 in Order IX (Instruments) to 1,224 in Order X (Textiles). A sample drawn to give the same proportion of

establishments from each Order would be inefficient in that it would contain too few firms from the small Orders to give any information, and many more than were necessary in the case of the large ones. It was decided, therefore, to draw a stratified sample, with Orders as strata. Samples were drawn from each Order in proportion to the square root of its representation in the population. This procedure was adopted because, if an average of any quantity (e.g. proportion of firms with graduates) is being sought, one calculated on the basis of such a sample is subject to minimum sampling error, provided that the variation within the different Orders is the same. (The method of calculating such averages is shown as a footnote to page 136.) As it turned out, such averages were not calculated ; but the proportions chosen gave a convenient distribution of firms to work on.

At this point it was decided that, for the purposes of this survey, rayon manufacture should be included in the same Order as chemical manufacture and not with textiles, on the grounds of similarity of technology ; and, further, that Order VI (Engineering) should be split into two parts—mechanical and electrical.

With these modifications in the Orders, it was decided to draw samples from each as far as possible at random ; the numbers in the various size-groups within any Order would, therefore, be more or less proportional to those in the Board of Trade figures. It is not possible to confirm that matters worked out like this, however, because of the distinction between a *firm* and an *establishment*. An establishment is a single works on one site, whilst a firm is the whole entity run by one management, which may contain any number of establishments. It ranges from the very loose association of more or less autonomous, subsidiary firms with no more than financial linking, to the closely integrated combine with organized common services and unified policy throughout. From the point of view of this investigation, the firm, rather than the establishment, is the important entity, at least as long as the organization is close enough for either information services, or policy on innovation and development, or both, to be common. There was no point in visiting establishment after establishment of the same combine to get the same information about common research facilities and common attitudes to the introduction of new ideas. (In a more intensive study of a few firms, however, a study of the differences occurring between one member establishment and another, in the speed of introducing common innovations, in awareness of the information available at the centre, and so on, would probably be very enlightening.) For this reason it is difficult

to make a fair comparison between the figures for establishments supplied by the Board of Trade and the figures for the firms actually visited.

173 of the establishments noted as belonging to these firms were members of fairly large combines, each having a common board of management, while 329 were either single-establishment firms, or were members of small combines of two or three establishments. These 329 establishments were distributed roughly as intended, except for the following discrepancies: Fewer establishments than intended in timber (since the population included many small timber yards hardly relevant to the inquiry), and in vehicles (because of the inflation of the total population with many small garages), and more than were intended in non-metalliferous mining and related industries (mainly abrasives). Further, there is a slight bias in favour of the larger firms in the case of vehicles (for the reason given above) and in textile manufacturing (because many of the very small establishments appear to be part of larger firms). Since the size distribution of the remaining 173 establishments was not known, or the extent to which the population as a whole was grouped into multi-establishment firms, a better check on the extent to which the sample is free from bias could not be made.

It has already been mentioned in Chapter I that the big national combines and the nationalized industries were deliberately excluded from the sample.

In the case of the multi-establishment firms, it was clearly possible that some or all of the associate establishments might be outside the area considered, and even that the headquarters and or the main research or information facilities might be elsewhere. One firm visited included the complete research and development departments required for the many establishments spread over the whole country, and carried such development right through to final installation. Four firms were branches of parent firms with headquarters in other parts of the country, and 4 more had headquarters outside the U.K. All 8 had research and development facilities at their headquarters. One British and one foreign firm also had research facilities in the area, and some of the others had development sections. In the analysis, all these 9 firms have been classified according to the main characteristics of that part falling inside the area surveyed.

As a result of the refusal by about 25 per cent of the firms approached to co-operate in this investigation, it is probable that there is a slight bias in favour of the firms with sources of scientific information or with scientifically trained staff. It is not thought,

however, that this bias is serious, especially as an attempt was made to replace such refusals by other firms in the same industry and size-group. In many cases, admission of the bias makes the case for believing in a low utilization of science in such firms even stronger. In certain of the calculations, averages have been calculated both for the sample of firms visited and for the same sample to which the 71 firms which failed to co-operate, and which are assumed to be without scientists or scientific contacts of any kind, were added.

Of the remaining firms, one, though visited, provided no information and possibly should be put in the same category as the refusals ; 23 proved to be wholly merchanting, very small workshops, or jobbing joiners and bricklayers, and were therefore hardly relevant to the survey. Three firms were not visited for lack of time. Taking it all round, the response can be considered statistically satisfactory.

The 225 firms actually visited were distributed as shown in Table 3. The total employment in these firms was 146,700 out of a total employment in the area in 1951 of 819,166 in the Standard Industrial Classification Orders surveyed.

Getting the Information

As described in Chapter I, the firms were approached in the first instance by letter. When an interview was granted, one or two of the observers would visit the firm and first meet a senior official, with whom they would discuss the type of information wanted. Where possible, further independent discussions with other relevant officials of the company were worked in ; the extent to which this was possible depended partly on the existence of such other possible informants, and partly on the atmosphere of the firm, readiness to agree to discussion with others varying a good deal. The amount of time spent depended on the complexity of the firm and the communicativeness of the informants. It was seldom less than two hours, was frequently about five hours and, in a few cases, ranged up to two days. Firms would often fill in details, especially of the numbers of staff and their qualifications, by subsequent correspondence.

At these interviews, the discussion was of the " open-ended " type, the investigators giving their informants their heads to discuss anything the latter might think relevant. In order to ensure that the ground of the survey was covered, however, the observers were provided with an *aide mémoire*, a copy of the final version of which is given on page 184. This served both as a check list of points

to be raised, and a scheme under which to organize information subsequently. As it turned out, replies under certain headings were so vague, or so vitiated by variations in the use of terms, that some of the topics in the *aide mémoire* have not subsequently been treated in this Report, more particularly relations with trade unions and suggestion schemes. " Professional bodies " to which the firm might belong were such a heterogeneous mixture of professional, technical, trade and other organizations that the answers under this head could not be used either.

Notes were taken, at the interview if possible, or, failing that, as soon as possible afterwards, as much information as possible being classified under the heads of the *aide mémoire*, with any other descriptive material thought important added as a supplement. In addition, firms were classified in certain categories in respect of the level of new development carried out, their general need for scientific staff and information, and the extent to which these needs were satisfied. It is freely admitted that the classification of firms on these lines is a subjective judgment of the interviewers. Nevertheless, in view both of their past experience, of that gained in this survey, and of the considerable discussion devoted to each firm by the interviewers, it is felt that the standards of judgment at least remained consistent. The firms, therefore, have been analysed to find the extent to which these subjectively assessed characteristics are associated with other, more objective ones.

In addition to the routine inquiries made in all cases, suitable firms were asked for details of successful or unsuccessful attempts to develop new ideas. The information thus obtained was not as useful as was hoped, on account of the reluctance of the firms to describe not only failures (which is very understandable), but even temporary setbacks which were later overcome.

Treatment of the Material

Though some of the conclusions drawn in the body of this Report have had to be based on broad impressions of the evidence obtained (or, being indications of what can occur, are backed up by single examples), they have in the main been based on the analysis of the figures for the whole sample, either as set out in the attached tables, or through more detailed cross-analyses.

The statistical techniques employed were extremely simple, and call for only brief description. First, tables have been prepared showing the extent to which certain of the characteristics appear in the whole sample or in certain classes of it. The two main

classifications used are size and industry grouping. As to the latter, it was clear that a further breakdown of the sample into the Orders of the Standard Industrial Classification would lead to individual numbers so small that no conclusions could safely be based on them. It was, therefore, necessary, even at the risk of the blurring of detail and of grouping together not wholly comparable groups of industry, to amalgamate the Orders into a smaller number of groupings. After much discussion, and the examination of some preliminary results to see that there was no positive evidence against what appeared logical groupings, the following scheme was adopted :

MODERN	Orders IV ; VI (minimum list headings 70–79 only) ; IX (except for 103) ; X (113 only) ; XIII (157 and two firms in 162 (miscellaneous) making dextrine and margarine respectively) ; XV (180 only) ; XVI (190 and 191).
ENGINEERING . . .	Orders V ; VI (50–69) ; VII ; VIII.
TEXTILES	Order X (except for 113).
MISCELLANEOUS . .	The rest.

The key to these Orders is given below.

PERTINENT ORDERS FROM THE STANDARD INDUSTRIAL CLASSIFICATION

Order III. *Treatment of non-metalliferous mining materials other than coal.* Bricks, fireclay, china, glass, cement, abrasives, asbestos, etc.

„ IV. *Chemicals and Allied Trades.* Chemicals, dyes, pharmaceuticals, explosives, paints, soap, glycerine, waxes, oils, gums, etc.

„ V. *Metal Manufacture.* Blast furnaces, iron and steel mills, foundries, tinplate, tubes, non-ferrous metals.

„ VI. *Engineering.* All branches of engineering, including electrical but excluding vehicles.

„ VII. *Vehicles.* Motor-cars, aeroplanes, locomotives, cycles, etc.

„ VIII. *Metal Goods.* Tools, bolts, forgings, wire, etc.

„ IX. *Precision Instruments, Musical Instruments, Jewellery.*

„ X. *Textiles, including Textile Finishing.*

„ XI. *Leather.* Tanning, dressing, making-up and furs.

„ XIII, *Food, Drink and Tobacco.*

„ XIV. *Manufacture of Wood and Cork.*

Order XV. *Paper and Printing.*
„ XVI. *Other Manufacturing Industries.* Rubber, linoleum, plastic mouldings, etc.

It must be emphasized that percentages of the whole sample (e.g. number of firms with graduates as percentages of all firms) are biased estimates of the corresponding percentages of the whole number of firms in the area. This is not only because of the elimination of certain classes of firms (e.g. clothing manufacturers, small garages, leather workers) from the sample, and the possible bias due to refusals. In addition, the stratification of the sample means that certain industry groups are represented by a much higher proportion of their total number than others. If, however, we assume that the ratio of establishments covered by the firms visited in each industry group to the total number of establishments in that industry group in the area is the same as the ratio of the number of firms visited in that group to the total number of firms in that group in the area, it is possible to make estimates of the proportions of firms in the area with assigned characteristics. The method employed of doing this is given in the footnote below.[1]

As it turned out, it did not seem worth re-calculating these averages, both because the effect of multi-establishment firms is to make the ratio of establishments to firms in an Order subject to a large sampling error, but even more because the figures, if

[1] Let number of firms in order i in the area $= \Phi_i$, of establishments H_i,
„ „ „ „ visited $= F_i$, of establishments covered by visits $= E_i$
„ „ „ „ visited, and having assigned characteristic $= f_i$,

then the estimated number of firms in the area in order i in the area with the assigned characteristic would be $f_i \frac{\Phi_i}{F_i}$,

and the estimated proportion of all firms having this characteristic would be

$$\frac{\sum_i f_i \cdot \frac{\Phi_i}{F_i}}{\sum_i \Phi_i}.$$

We do not however know Φ_i; but if we assume that $\frac{\Phi_i}{F_i} = \frac{H_i}{E_i}$, this estimate becomes

$$\frac{\sum_i f_i \cdot \frac{H_i}{E_i}}{\sum_i F_i \cdot \frac{H_i}{E_i}}.$$

obtained, did not appear to be of any very great use. However, as an example of the sort of difference that this re-calculation may make, the percentage of firms visited having graduate staff is 34·5, while the estimate re-calculated as above is 29·4.

Secondly, the more important characteristics were analysed for association with each other, two-by-two or larger tables being drawn up and apparent associations tested by the chi-square test for significance. (Where numbers in the compartments were large, the ordinary formula was used ; where small, the exact, multinomial test.) In some cases, the numbers were large enough to allow testing for associations of characteristics within classes so as to separate out effects that might be due to mutual correlation of two characteristics with a third.

It may be worthy of mention here that (following a suggestion of D. J. Urquhart) Hollerith cards were found to be a handy way of quickly finding the numbers of firms with a given combination of characteristics. Instead of having a card for each firm with holes punched in it for characteristics in assigned places, each characteristic had a card for itself and the hole corresponding to the report number of the firm was punched if the firm had that characteristic. Thus the number of firms with several assigned characteristics was quickly found by placing the cards for these characteristics on top of one another in register, and seeing for how many holes daylight showed through.

LIST OF TABLES

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TABLE 1

[*Chapter II*]

Total Establishments in the Area of the Survey: Analysed by Size-Groups and Industrial Grouping (as at December 1950)

Number of employees per establishment	Industrial grouping				
	Modern	Engineering	Textile	Miscellaneous	Total
10–19	215	442	208	545	1,410
20–49	228	406	360	465	1,459
50–99	167	222	342	151	882
100–249	148	184	548	109	989
250–499	78	66	276	30	450
500–999	32	33	52	11	128
1,000 and over	20	31	6	3	60
Total for establishments with 50 or over	445	536	1,224	304	2,509

TABLE 2

[*Chapter II*]

Establishments covered by the Survey

The Survey covered 502 establishments each employing more than 50 persons.

Number of employees per establishment	Industrial grouping				
	Modern	Engineering	Textile	Miscellaneous	Total
50–99	34	27	16	28 } + 14‡	(112)
100–249	19	37	29 + 151†	21 }	(264)
250–499	29	6	31	2	68
500–999	9	8	13	2	32
1,000 and over	5	8 + 8*	1	4	26
Total establishments	96	86 + 8	90 + 151	57 + 14	502
Total employees	28,200	53,800	47,700	17,000	146,700

* The firm visited is the Research service of a group of 9 parent firms.

† Five multiple establishment firms are covered by this figure; actual size of each establishment of the 151 included not definitely known.

‡ One brickmaking firm had 14 other establishments in the area, all of small size.

TABLE 3

[*Chapter II*]

Analysis of the Firms visited by Industry Groups, Size Classification and Total Numbers of Employees

No. of employees per firm	Modern		Engineering		Textile		Miscellaneous		Total	
	Firms	Employees	Firms	Employees	Firms	Employees	Firms	Employees	Firms	Employees
50–99 . .	11	600	17	1,000	5	400	18	1,200	51	3,200
100–249 . .	17	2,600	30	5,100	14	1,700	19	3,300	80	12,700
250–499 . .	11	4,100	5	2,100	11	4,900	2	900	29	12,000
500–999 . .	13	9,200	8	5,200	14	10,100	5	3,600	40	28,100
1,000 and over .	6	11,700	8	40,400	7	30,600	4	8,000	25	90,700
Totals . .	58	28,200	68	53,800	51	47,700	48	17,000	225	146,700

TABLES 4–11

[*Chapter II*]

Distribution of Scientists and Technologists

4–6. by Firms visited 7–8. by Industry Groups
9–11. by Size-Groups

4. BY FIRMS VISITED : GRADUATES

A total of 684 graduates* in 99 firms were found distributed as under.

Industry	Total number of firms visited	Number of firms with Graduates	Total number of Graduates	Number of firms with Graduates on the Directorate	Number of Graduate Directors	Number of firms employing Graduates†	Number of Graduates on Staff†	Total number employed in these firms	Number of Graduates per 1,000 employees
Modern . .	58	44	400	29	39	39	361	28,000	14
Engineering .	68	26	170	20	31	20	139	53,000	3·1
Textile . .	51	16	74	14	15	8	59	47,500	1·5
Miscellaneous	48	13	40	7	8	10	32	17,000	2·3
Total . . .	225	99	684	70	93	77	591	145,500	4·7

* † Throughout these Tables " graduate " means a university graduate in *Science or Technology*, i.e. other than directors.

5. BY FIRMS VISITED : HOLDERS OF DIPLOMAS

A total of 613 Diploma-Holders in 73 firms were found distributed as under.

Industry	Total number of firms visited	Number of firms with Diploma-Holders	Total number of Diploma-Holders	Number of firms with Diploma-Holders on the Directorate	Number of such Directors	Number of firms employing Diploma-Holders*	Number of Diploma-Holders on Staff*	Total number employed in these firms	Number of Diploma-Holders per 1,000 employees
Modern . .	58	29	251	10	11	28	240	28,000	9·2
Engineering .	68	26	295	10	15	20	280	53,000	5·65
Textile . .	51	7	32	2	3	5	29	47,500	0·7
Miscellaneous	48	11	35	4	6	8	29	17,000	2·1
Total . . .	225	73	613	26	35	61	578	145,500	4·2

* i.e. other than directors.

6. BY FIRMS VISITED : SCIENTIST/TECHNOLOGISTS

A total of 1,297 such men (Graduates and Diploma-Holders) were found spread over 118 firms as under.

Industry	Total number of firms visited	Number of firms with Scientist/ Technologists	Total number of Scientist/ Technologists	Number of firms with Scientist/ Technologists on the Directorate	Number of such Directors	Number of firms employing Scientist/ Technologists*	Number of Scientist/ Technologists on Staff*	Total number employed in these firms	Number of Scientist/ Technologists per 1,000 employees
Modern . .	58	48	651	35	50	43	601	28,000	23·2
Engineering .	68	34	465	28	46	26	419	53,000	8·7
Textile . .	51	18	106	16	18	10	88	47,500	2·2
Miscellaneous	48	18	75	9	14	13	61	17,000	4·4
Total . . .	225	118	1,297	88	128	92	1,169	145,500	8·9

* i.e. other than directors.

7. BY INDUSTRY GROUPS: GRADUATES

Number of Graduates per firm	Modern		Engineering		Textiles		Miscellaneous		All Groups	
	No. of firms	No. of Graduates	No. of firms	No. of Graduates	No. of firms	No. of Graduates	No. of firms	No. of Graduates	No. of firms	No. of Graduates
None	14	—	42	—	35	—	35	—	126	—
1	11	11	9	9	9	9	7	7	36	36
2	7	14	7	14	4	8	2	4	20	40
3	6	18	3	9	1	3	—	—	10	30
4–5	7	29	2	8	—	—	1	4	10	41
6–10	4	31	—	—	1	7	3	25	8	63
11–17	—	—	—	—	—	—	—	—	—	—
Over 17	9	297	5	130	1	47	—	—	15	474
Totals	58	400	68	170	51	74	48	40	225	684

8. BY INDUSTRY GROUPS : DIPLOMA-HOLDERS

Number of Diploma-Holders per firm	Modern		Engineering		Textiles		Miscellaneous		All Groups	
	No. of firms	No. of Diploma-Holders	No. of firms	No. of Diploma-Holders	No. of firms	No. of Diploma-Holders	No. of firms	No. of Diploma-Holders	No. of firms	No. of Diploma-Holders
None	29	—	42	—	44	—	37	—	152	—
1	4	4	9	9	2	2	5	5	20	20
2	5	10	6	12	2	4	2	4	15	30
3	1	3	1	3	2	6	2	6	6	18
4–5	6	27	3	14	—	—	—	—	9	41
6–10	8	71	1	6	—	—	2	20	11	97
11–17	1	14	—	—	—	—	—	—	1	14
Over 17	4	122	6	251	1	20	—	—	11	393
Totals	58	251	68	295	51	32	48	35	225	613

9. BY SIZE-GROUPS : GRADUATES

Number of Graduates per firm	Size-Group										All sizes	
	50–99		100–249		250–499		500–999		1,000 and over			
	No. of firms	No. of Graduates	No. of firms	No. of Graduates	No. of firms	No. of Graduates	No. of firms	No. of Graduates	No. of firms	No. of Graduates	No. of firms	No. of Graduates
None . . .	41	—	53	—	14	—	16	—	2	—	126	—
1 . .	5	5	16	16	2	2	9	9	4	4	36	36
2 . .	2	4	5	10	5	10	5	10	3	6	20	40
3 . .	—	—	4	12	4	12	—	—	2	6	10	30
4–5 . .	2	8	1	4	2	9	3	12	2	8	10	41
6–10 . .	1	8	1	9	1	8	2	15	3	23	8	63
11–17 . .	—	—	—	—	—	—	—	—	—	—	—	—
Over 17 . .	—	—	—	—	1	21	5	205	9	248	15	474
Totals . .	51	25	80	51	29	62	40	251	25	295	225	684

10. BY SIZE-GROUPS : DIPLOMA-HOLDERS

Number of Diploma-Holders per firm	Size-Group										All sizes	
	50–99		100–249		250–499		500–999		1,000 and over			
	No. of firms	No. of Diploma-Holders	No. of firms	No. of Diploma-Holders	No. of firms	No. of Diploma-Holders	No. of firms	No. of Diploma-Holders	No. of firms	No. of Diploma-Holders	No. of firms	No. of Diploma-Holders
None . . .	48	—	58	—	20	—	21	—	5	—	152	—
1 . .	1	1	13	13	2	2	2	2	2	2	20	20
2 . .	—	—	5	10	2	4	6	12	2	4	15	30
3 . .	—	—	2	6	1	3	1	3	2	6	6	18
4–5 . .	1	4	2	9	3	14	1	4	2	10	9	41
6–10 . .	1	10	—	—	1	6	7	61	2	20	11	97
11–17 . .	—	—	—	—	—	—	1	14	—	—	1	14
Over 17 . .	—	—	—	—	—	—	1	50	10	343	11	393
Totals . .	51	15	80	38	29	29	40	146	25	385	225	613

11. BY SIZE-GROUPS: GRADUATES AND DIPLOMA-HOLDERS

Size-Group	Total number of firms visited	Number of firms with Graduates	Number of Graduates	Number of firms with Diploma-Holders	Number of Diploma-Holders	Number of firms with Scientist/ Technologists	Number of Scientist/ Technologists
50–99 . . .	51	10	25	3	15	11	40
100–249 . . .	80	27	51	22	38	39	89
250–499 . . .	29	15	62	9	29	17	91
500–999 . . .	40	24	251	19	146	27	397
1,000 and over . .	25	23	295	20	385	24	680
Total	225	99	684	73	613	118	1,297

TABLE 12 (i–iii)

[*Chapter II*]

Association of Qualifications of Directorate and of Staff

The following tables show, for the whole sample, for the size-groups and for the industry groups, the extent to which the firms that have scientist/technologists on the Board are those that employ them on the Staff.

12 (i). Whole Sample

Highest qualification on the *Staff* is	Number of firms in which the highest qualification on the *Board* is			Total
	Degree	Diploma	Neither	
Degree	48	7	22	77
Diploma	2	4	8	14
Neither	20	7	107	134
Total	70	18	137	225

Table 12. Directorate and Staff

12 (ii). Analysis of Firms by Size and Scientific Qualifications of Board and Staff

Highest qualification: on the Board →	Degree			Diploma			Nil		
Highest qualification: on the Staff →	Deg.	Dip.	Nil	Deg.	Dip.	Nil	Deg.	Dip.	Nil
Size	Total firms								
50–99	51	5	—	5	—	—	—	—	1	40
100–249	80	7	2	9	2	3	6	7	3	41
250–499	29	11	—	2	—	—	1	3	—	12
500–999	40	12	—	3	3	1	—	5	3	13
1,000 and over	25	13	—	1	2	—	—	7	1	1
Total	225	48	2	20	7	4	7	22	8	107

12 (iii). ANALYSIS OF FIRMS BY INDUSTRY GROUPS AND SCIENTIFIC QUALIFICATIONS OF BOARD AND STAFF

Highest qualification: on the Board →		Degree			Diploma			Nil		
Highest qualification: on the Staff →		Deg.	Dip.	Nil	Deg.	Dip.	Nil	Deg.	Dip.	Nil
Industry Group	Total firms									
Modern	58	24	1	4	3	3	—	12	1	10
Engineering	68	14	—	6	3	1	4	3	3	34
Textile	51	6	—	8	1	—	1	1	1	33
Miscellaneous	48	4	1	2	—	—	2	6	3	30
Total	225	48	2	20	7	4	7	22	8	107

A more detailed analysis of the influence of size-group and industry adds little to the information which is contained in Table 12 (i) for the whole sample. The tendency for more firms than could reasonably be expected to fall into the classes " Graduate on Board : Graduate on Staff " and " no qualified person on Board or Staff " is noticeable in all the groups. The passage from the latter (no qualified person on either) to the former (Graduate on both), as the firms grow larger, is also striking. The high proporton of firms in the category " Neither " is equally marked in all of the industry groups with the exception of the " Modern " one.

TABLES 13–15

[*Chapter III*]

Distribution of Scientific Personnel classified among Firms by Nature of Scientific Work carried on

13. Graduates 14. Diploma-Holders
15. Scientist/Technologists

The following three tables, 13–15, show the distributions of qualified staff among firms classified according to the nature of the most sophisticated scientific work done in the firm. The classes are defined as follows :

Research and/or Development : Scientific research devoted to the finding of new knowledge, whether of a general nature or specifically applicable to immediate problems ; and/or scientific development to convert new knowledge to practical use.
Established Principles : Routine application of existing scientific knowledge to improve or extend the processes or products of the firm.
Adoption from Outside : The firm uses qualified staff to facilitate the introduction of innovations developed elsewhere.
Control, Testing and Management : Qualified staff are used only for process control, testing, etc., or in managerial positions.

It should be noted that firms in any category may be expected to employ some of their qualified staff on work described in succeeding categories.

13. Graduates

Type of work done	Number of such firms with Graduates	Number of Graduates	Number of firms with Graduates on Directorate	Number of Graduate Directors in these	Number of firms with Graduates on Staff	Number of Graduate Staff in these
Research and/or Development . .	42	555	29	41	39	514
Established principles	26	72	19	29	19	43
Adoption from outside, etc. . . .	14	34	11	12	11	22
Control, Testing and Management .	17	23	11	11	8	12
Total	99	684	70	93	77	591

14. DIPLOMA-HOLDERS

Type of work done	Number of such firms with Diploma-Holders	Number of Diploma-Holders	Number of firms with Diploma-Holders on Directorate	Number of Diploma-Holder Directors in these	Number of firms with Diploma-Holders on Staff	Number of Diploma-Holder Staff in these
Research and/or Development . .	33	466	9	9	31	457
Established principles	16	58	6	8	12	50
Adoption from outside, etc. . . .	12	57	5	8	9	49
Control, Testing and Management .	12	32	6	10	9	22
Total	73	613	26	35	61	578

15. SCIENTIST/TECHNOLOGISTS

Type of work done	Number of such firms with Scientist/ Technologists	Number of Scientist/ Technologists	Number of firms with Scientist/ Technologists on Directorate	Number of Scientist/ Technologist Directors in these	Number of firms with Scientist/ Technologists on Staff	Number of Scientist/ Technologists on Staff in these
Research and/or Development . .	44	1,021	32	50	41	971
Established principles	31	130	24	37	23	93
Adoption from outside, etc. . . .	19	91	16	20	15	71
Control, Testing and Management .	24	55	16	21	13	34
Total	118	1,297	88	128	92	1,169

TABLES 16–18

[*Chapter III*]

Distribution of Firms classified according to Research and Development Facilities

16. by Industry Groups 17. by Size-Groups
18. by Numbers of Graduates

16. BY INDUSTRY GROUPS

Facilities	Number of firms				
	Modern	Engineering	Textile	Miscellaneous	All Groups
Own Research Department	14	7	4	5	30
External Research Department * / Own Development ,,	6	2	—	2	10
External Research ,, / No Development ,,	—	1	—	2	3
No Research ,, / Own Development ,,	22	13	8	6	49
No Research ,, / No Development ,,	16	45	39	33	133
Total	58	68	51	48	225

* Firms classified as having an external research department had no research department of their own in the greater Manchester area, but relied on the research department of a parent or associated company elsewhere.

17. BY SIZE-GROUPS

Facilities	Number of firms					
	50–99	100–249	250–499	500–999	1,000 and over	Total
Own Research Department	2	5	2	8	13	30
External Research Department } Own Development ,, } . . .	1	—	1	6	2	10
External Research ,, } No Development ,, } . . .	—	2	1	—	—	3
No Research ,, } Own Development ,, } . . .	4	17	11	11	6	49
No Research ,, } No Development ,, } . . .	44	56	14	15	4	133
Total	51	80	29	40	25	225

18. BY NUMBERS OF GRADUATES

Facilities	Firms with the given number of Graduates								
	Over 17	11–17	6–10	4–5	3	2	1	Nil	Number of firms in Group
Own Research Department . . .	10	—	7	3	1	4	5	—	30
External Research Department Own Development ,, . . .	4	—	—	—	—	2	—	4	10
External Research ,, No Development ,, . . .	—	—	—	1	—	1	—	1	3
No Research ,, Own Development ,, . . .	1	—	1	5	7	6	16	13	49
No Research ,, No Development ,, . . .	—	—	—	1	2	7	15	108	133
Total	15	—	8	10	10	20	36	126	225

TABLES 19–22

[Chapter III]

Distribution of Firms classified according to Type of Development

19. by Industry Groups
20. by Size-Groups
21. by Numbers of Graduates
22. by Research and Development Facilities

The following tables, 19–22, show how firms fall into various categories, when classified ccording to the type of development they do. The placing of a firm in one class or another vas a subjective judgment of the investigators ; but mutual discussion among all the investi- ators, and comparisons with firms previously visited, gave reasonable confidence that the asis of comparison remained fixed. The classes were defined as follows :

Ideas based on Research : The firm is making, or seeking to make, innovations based on the results of its own research or of research only recently published and not yet part of the general intellectual atmosphere of industry.

Established principles : The firm is making, or seeking to make, innovations based on systematic application of existing scientific knowledge. (Much invention falls into this category.)

Ready adoption : The firm, while developing nothing new of its own, regularly looks out for innovations developed elsewhere that might be of value to it.

Minor innovation : The firm introduces only minor changes into its products or processes.

Firms not attaining the latter standard are classified as having no vigorous development olicy.

19. by Industry Groups

Type of Development	Number of firms in the Industry Group				
	Modern	Engineering	Textile	Miscellaneous	All Groups
Ideas based on Research .	24	8	4	8	44
Established principles .	18	16	3	2	39
Ready adoption of ideas developed elsewhere .	2	2	11	4	19
Minor innovation . . .	3	12	5	2	22
No energetic development	11	30	28	32	101
Total	58	68	51	48	225

20. by Size-Groups

Type of Development	Number of firms in the Size-Group					
	50–99	100–249	250–499	500–999	1,000 and over	All sizes
Ideas based on Research .	3	10	6	11	14	44
Established principles . .	3	15	7	9	5	39
Ready adoption of ideas developed elsewhere . .	3	6	6	3	1	19
Minor innovation . . .	4	10	2	4	2	22
No energetic development .	38	39	8	13	3	101
Total	51	80	29	40	25	225

21. BY NUMBERS OF GRADUATES

Type of Development	Number of firms with the number of Graduates								
	Over 17	11–17	6–10	4–5	3	2	1	Nil	Number of firms in Group
Ideas based on Research	14	—	7	4	3	7	7	2	44
Established principles	1	—	—	3	6	5	11	13	39
Ready adoption of ideas developed elsewhere	—	—	1	1	—	2	1	14	19
Minor innovation	—	—	—	1	1	3	4	13	22
No energetic development	—	—	—	1	—	3	13	84	101
Total	15	—	8	10	10	20	36	126	225

22. BY RESEARCH AND DEVELOPMENT FACILITIES

Research or Development facilities	Ideas from Research	Established principles	Ready adoption	Minor innovation	No energetic development	Total
Own Research Department	30	—	—	—	—	30
External Research Department Own Development ,, . . .	5	2	—	1	2	10
External Research ,, No Development ,, . . .	3	—	—	—	—	3
No Research ,, Own Development ,, . . .	6	25	6	7	5	49
No Research ,, No Development ,, . . .	—	12	13	14	94	133
Total	44	39	19	22	101	225

TABLE 23 (i–iii)

[Chapter III]

Association of the Qualifications of the Directorate and of the Staff in Firms carrying out Various Types of Development

Table 23 (i–iii) gives the results for the relationship between the type of development work carried out by the firm and the qualifications of those on the Board and Staff. More detailed analyses on the lines of Table 12 (i) have been carried out for the two extreme cases where development is based on research and where there is no energetic development policy respectively. Table 23 (ii) shows the tendency of the highest qualification on the Board and on the Staff to be the same. When this association is allowed for there still remains evidence that the more sophisticated types of development appear to be more strongly associated with the presence of Graduates on the Staff than with Graduates on the Board. Table 23 (iii) shows even more clearly that the result of the absence of the Scientist/Technologists from the Board and Staff leads to an absence of any evidence of a vigorous development policy.

23 (i). Type of Development according to the Qualifications of Board and Staff

Type of Development	Total no. of firms	Number of firms in which highest qualification on the Board is :								
		Degree			Diploma			Nil		
		Highest qualification on Staff								
		Deg.	Dip.	Nil	Deg.	Dip.	Nil	Deg.	Dip.	Nil
Ideas based on Research . .	44	26	—	3	1	1	1	12	—	—
Established principles . . .	39	12	1	6	2	1	2	5	2	8
Ready adoption of ideas developed elsewhere . . .	19	4	—	—	1	—	1	—	2	11
Minor innovation	22	4	—	3	1	2	—	1	—	11
No energetic development . .	101	2	1	8	2	—	3	4	4	77
Total	**225**	**48**	**2**	**20**	**7**	**4**	**7**	**22**	**8**	**107**

23 (ii). ANALYSIS OF 44 FIRMS WHOSE DEVELOPMENT IS BASED ON RESEARCH

Highest qualification on Staff	Number of firms in which the highest qualification on Board is :			
	Degree	Diploma	Neither	Total
Degree	26	1	12	39
Diploma	—	1	—	1
Neither	3	1	—	4
Total	29	3	12	44

23 (iii). ANALYSIS OF 101 FIRMS WHICH HAVE NO ENERGETIC DEVELOPMENT POLICY

Highest qualification on Staff	Number of firms in which the highest qualification on Board is :			
	Degree	Diploma	Neither	Total
Degree	2	2	4	8
Diploma	1	—	4	5
Neither	8	3	77	88
Total	11	5	85	101

TABLES 24–25

[*Chapter IV*]

Distribution of Firms according to Membership of Research Associations

24. by Industry Groups 25. by Size-Groups

24. BY INDUSTRY GROUPS

Type of membership	Number of firms in the Industry Group				
	Modern	Engineering	Textile	Miscellaneous	Total
Membership of 1 Research Assoc.	24	23	37	17	101
Membership of 2 Research Assocs.	10	6	5	2	23
Membership of 3 or more Research Assocs.	6	3	5	—	14
Facilities through trade assocs.	1	9	—	3	13
Total firms with members' privileges	41 (71%)	41 (60%)	47 (92%)	22 (46%)	151 (67%)
Eligible but not members	4	11	2	3	20
Main product not covered by a Research Assoc.	12	14	2	22	50
Not eligible owing to foreign connections	1	2	—	1	4
Total	58	68	51	48	225

25. BY SIZE-GROUPS

Type of membership	Number of firms in Size-Group					
	50–99	100–249	250–499	500–999	1,000 and over	Total
Membership of 1 Research Assoc.	18	33	19	23	8	101
Membership of 2 Research Assocs.	—	7	5	6	5	23
Membership of 3 or more Research Assocs.	1	—	1	5	7	14
Facilities through trade assocs.	2	9	—	—	2	13
Total firms with members' privileges	21 (41%)	49 (61%)	25 (86%)	34 (85%)	22 (88%)	151 (67%)
Eligible but not members	6	10	2	1	1	20
Main product not covered by a Research Assoc.	24	20	2	3	1	50
Not eligible owing to foreign connections	—	1	—	2	1	4
Total	51	80	29	40	25	225

TABLES 26–27

[Chapter IV]

Distribution of Firms according to Nature of Contact with Research Associations

26. by Industry Groups 27. by Size-Groups

26. BY INDUSTRY GROUPS

Firms making	Number of firms in Industry Group				
	Modern	Engineering	Textile	Miscellaneous	Total
Frequent consultations . . .	23	15	25	9	72
Occasional consultations . .	16	13	20	9	58
Total	39 (95%)	28 (68%)	45 (96%)	18 (82%)	130 (86%)
Total firms in Group . . .	41	41	47	22	151
Visits to Research Assoc. . .	24 (58%)	20 (49%)	29 (62%)	11 (50%)	84 (56%)
Visits from Research Assoc. .	23 (56%)	19(46%)	38 (81%)	11 (50%)	91 (60%)

NOTE.—In this table and the following three, the analysis covers only firms which are members or which have facilities through Trade Association membership.

27. BY SIZE-GROUPS

Firms making	Number of firms in Size-Group					
	50–99	100–249	250–499	500–999	1,000 and over	Total
Frequent consultations	5	18	14	17	18	72
Occasional consultations	9	20	10	16	3	58
Total . .	14 (66%)	38 (77%)	24 (96%)	33 (97%)	21 (96%)	130 (86%)
Total firms in Group	21	49	25	34	22	151
Visits to Research Association . . .	9 (43%)	20 (41%)	16 (64%)	21 (62%)	18 (82%)	84 (56%)
Visits from Research Association . . .	10 (48%)	22 (45%)	19 (76%)	21 (62%)	19 (86%)	91 (60%)

TABLES 28–29

[*Chapter IV*]

Distribution of the Firms which are Members of the British Cotton Industry Research Association (Shirley Institute) according to the Nature of Contact with the Institute

28. by Industry Groups 29. by Size-Groups

28. BY INDUSTRY GROUPS

Firms making	Number of firms in Industry Group				
	Modern	Engineering	Textile	Miscellaneous	Total
Frequent consultations	5	4	24	—	33
Occasional consultations	—	4	19	1	24
Total	5 (83%)	8 (100%)	43 (98%)	1 (100%)	57 (97%)
Total firms in Group	6	8	44	1	59
Visits to Research Assoc.	4 (67%)	5 (62%)	27 (61%)	—	36 (61%)
Visits from Research Assoc.	4 (67%)	6 (75%)	37 (68%)	—	47 (80%)

29. BY SIZE-GROUPS

Firms making	Number of firms in Size-Group					
	50–99	100–249	250–499	500–999	1,000 and over	Total
Frequent consultations	1	8	6	10	8	33
Occasional consultations	3	9	4	7	1	24
Total	4 (80%)	17 (100%)	10 (100%)	17 (95%)	9 (100%)	57 (97%)
Total firms in Group	5	17	10	18	9	59
Visits to Research Association	2 (40%)	10 (59%)	4 (40%)	12 (67%)	8 (90%)	36 (61%)
Visits from Research Association	3 (60%)	12 (70%)	9 (90%)	14 (78%)	9 (100%)	47 (80%)

TABLES 30–35

[Chapter V]

Distribution of Firms according to Nature of Consultation with Universities and Technical Colleges

30. by Industry Groups
31. by Size-Groups
32. by Qualifications of Directorate and Staff
33. by Numbers of Graduates
34. by Research and Development Facilities
35. by Type of Development

30. BY INDUSTRY GROUPS

	Number of firms in the Industry Group				
	Modern	Engineering	Textile	Miscellaneous	All Groups
Number of firms in Group . .	58	68	51	48	225
Nature of Consultation :					
Technical Problems only . .	10	11	4	7	32
,, ,, and Recruitment	20	13	5	7	45
Recruitment only	2	3	4	3	12
Total Consultations	32 (55%)	27 (40%)	13 (25%)	17 (35%)	89 (40%)
Consultations were made up as follows :					
Technical Problems (regular)	14	8	6	7	35
,, ,, (occasional)	16	16	3	7	42
Total Consultations on Technical Problems	30	24	9	14	77
Total Consultations on Recruitment	22	16	9	10	57

31. BY SIZE-GROUPS

	Number of firms in the Size-Group					
	50–99	100–249	250–499	500–999	1,000 and over	All sizes
Number of firms in Group	51	80	29	40	25	225
Nature of Consultation :						
Technical Problems only	5	14	5	5	3	32
,, ,, and Recruitment	4	9	6	13	13	45
Recruitment only	1	2	5	3	1	12
Total Consultations	10 (20%)	25 (31%)	16 (55%)	21 (52%)	17 (68%)	89 (40%)
Consultations were made up as follows :						
Technical Problems (regular)	3	8	4	8	12	35
,, ,, (occasional)	6	15	7	10	4	42
Total Consultations on Technical Problems. . .	9	23	11	18	16	77
Total Consultations on Recruitment	5	11	11	16	14	57

32. BY QUALIFICATIONS OF DIRECTORATE AND STAFF

	Firms thus consulting with					
	Director Graduate	Director Diploma-Holder	Staff Graduate	Staff Diploma-Holder	No Graduate or Diploma-Holder	All firms
Number of firms in Group	70	21	21	6	107	225
Nature of Consultation :						
Technical Problems only	11	4	3	2	12	32
,, ,, and Recruitment	31	4	5	—	5	45
Recruitment only	7	—	3	—	2	12
Total Consultations	49 (70%)	8 (38%)	11 (52%)	2 (33%)	19 (18%)	89 (40%)
Consultations were made up as follows :						
Technical Problems (regular)	22	2	5	—	6	35
,, ,, (occasional)	20	6	3	2	11	42
Total Consultations on Technical Problems. . .	42	8	8	2	17	77
Total Consultations on Recruitment	38	4	8	—	7	57

33. BY NUMBERS OF GRADUATES

	Number of firms thus consulting with number of Graduates									
	Over 17	11–17	6–10	4–5	3	2	1	Total firms with Graduates	Nil	All numbers
Number of firms in Group	15	—	8	10	10	20	36	99	126	225
Nature of Consultation :										
Technical Problems only	1	—	2	2	3	2	5	15	17	32
Technical Problems and Recruitment . . .	13	—	5	6	4	5	4	37	8	45
Recruitment only . .	—	—	—	1	1	5	3	10	2	12
Total Consultations . .	14 (93%)	—	7 (87%)	9 (90%)	8 (80%)	12 (60%)	12 (33%)	62 (62%)	27 (21%)	89 (40%)
Consultations were made up as follows :										
Technical Problems (regular)	11	—	4	5	2	5	1	28	7	35
Technical Problems (occasional) . . .	3	—	3	3	5	2	8	24	18	42
Total Consultations on Technical Problems .	14	—	7	8	7	7	9	52	25	77
Total Consultations on Recruitment	13	—	5	7	5	10	7	47	10	57

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34. BY RESEARCH AND DEVELOPMENT FACILITIES

	Number of firms thus consulting with					
	Own Research Department	External Research Department, own Development Department	External Research Department only	No Research Department, own Development Department	No facilities	All types
Number of firms in Group	30	10	3	49	133	225
Nature of Consultation :						
Technical Problems only	4	—	—	9	19	32
,, ,, and Recruitment	19	6	—	10	10	45
Recruitment only	—	1	1	6	4	12
Total Consultations	23 (77%)	7 (70%)	1 (33%)	25 (51%)	33 (25%)	89 (40%)
Consultations were made up as follows :						
Technical Problems (regular)	17	5	—	6	7	35
,, ,, (occasional)	6	1	—	13	22	42
Total Consultations on Technical Problems. . .	23	6	—	19	29	77
Total Consultations on Recruitment	19	7	1	16	14	57

35. BY TYPE OF DEVELOPMENT

	Number of firms thus consulting with type of development					
	Ideas from Research	Established principles	Ready adoption	Minor innovation	No energetic development	All types
Number of firms in Group	44	39	19	22	101	225
Nature of Consultation :						
Technical Problems only	5	6	6	3	12	32
,, ,, and Recruitment	25	9	2	3	6	45
Recruitment only	1	5	1	2	3	12
Total Consultations	31 (70%)	20 (51%)	9 (47%)	8 (36%)	21 (21%)	89 (40%)
Consultations were made up as follows :						
Technical Problems (regular)	21	6	2	1	5	35
,, ,, (occasional)	9	9	6	5	13	42
Total Consultations on Technical Problems. . .	30	15	8	6	18	77
Total Consultations on Recruitment	26	14	3	5	9	57

TABLES 36–37

[Chapter VI]

Numbers of Firms using Various Sources of Technical Help

36. by Industry Groups 37. by Size-Groups

36. BY INDUSTRY GROUPS

Source of help	Industry Group				
	Modern	Engineering	Textile	Miscellaneous	All types
Technical consultants .	19 (30%)	23 (34%)	8 (16%)	11 (23%)	61 (27%)
of which : permanent .	6	1	3	2	12
ad hoc . .	13	22	5	9	49
Consultants on management, work study, time and motion study, etc. .	7	6	19	6	38
Consultants on building .	6	5	4	8	23
D.S.I.R. and other Government-supported organizations	11 (19%)	15 (22%)	2 (4%)	11 (23%)	39 (17%)
Suppliers	26 (45%)	21 (31%)	31 (61%)	13 (27%)	91 (40%)
Customers	11 (19%)	15 (22%)	8 (16%)	8 (17%)	42 (19%)
All firms in Group . .	58	68	51	48	225

37. BY SIZE-GROUPS

Source of help	Size-Group					
	50–99	100–249	250–499	500–999	1,000 and over	All firms
Technical consultants	8 (16%)	25(31%)	9 (31%)	13 (32%)	6 (24%)	61 (27%)
of which : permanent	2	3	1	6	—	12
ad hoc .	6	22	8	7	6	49
Consultants on management, work study, time and motion study, etc. . . .	3	10	5	11	9	38
Consultants on building	4	7	5	3	4	23
D.S.I.R. and other Government-supported organizations	10 (20%)	8 (10%)	6 (20%)	5 (12%)	10 (40%)	39 (17%)
Suppliers	16 (31%)	38 (47%)	14 (49%)	14 (35%)	9 (36%)	91 (40%)
Customers . . .	9 (18%)	14 (17%)	5 (17%)	6 (15%)	8 (32%)	42 (19%)
All firms in Group .	51	80	29	40	25	225

TABLE 38 (i–iv)

[*Chapter VI*]

Numbers of Firms which have used or favour use of Sponsored Research

i. Industry Groups

Industry Group	Total number in Group	Number of firms interested in Sponsored Research	
Modern . .	58	12	20%
Engineering .	68	5	7%
Textile . .	51	6	12%
Miscellaneous	48	5	10%
Total . .	225	28	12·5%

ii. Size-Groups

Size-Group	Total number in Group	Number of firms interested in Sponsored Research	
50– 99 .	51	1	2%
100–249 .	80	10	12%
250–499 .	29	5	17%
500–999 .	40	5	12%
1,000 and over	25	7	28%
Total . .	225	28	12·5%

iii. Research Facilities

Research facilities	Total number in Group	Number of firms interested in Sponsored Research	
Own Research	30	9	30%
External Research, own Development . .	10	3	30%
External Research, no Development . .	3	—	—
No Research, own Development . . .	49	8	16%
No Research or Development	133	8	6%
Total	225	28	12·5%

iv. Qualification of Board and Staff

Qualification	Total number in Group	Number of firms interested in Sponsored Research	
Both Director and Staff Graduate . . .	48	12	25%
Director Graduate, not Staff	22	4	18%
Staff Graduate, not Director	29	8	24%
No Graduates	126	4	3%
Total	225	28	12·5%

TABLE 39 (i and ii)

[Chapter VI]

Numbers of Firms with Corporate Membership of Learned or Technical Societies

i. INDUSTRY GROUPS

Industry Group	Total number in Group	Number of firms Corporate members	%
Modern . .	58	17	29
Engineering .	68	12	18
Textile . .	51	8	16
Miscellaneous	48	7	16
Total . .	225	44	20

ii. SIZE-GROUPS

Size-Group	Total number in Group	Number of firms Corporate members	%
50– 99 .	51	10	20
100–249 .	80	8	10
250–499 .	29	7	24
500–999 .	40	9	22
1,000 and over	25	10	40
Total . .	225	44	20

TABLE 40 (i and ii)

[Chapter VI]

Numbers of Firms classified according to their Relations with the National Research Development Corporation

i. Industry Groups

Industry Group	Total number in Group	Number of firms aware of N.R.D.C. before interview	Number of firms which had received ideas from N.R.D.C. or sent suggestions to it	Number of firms interested in N.R.D.C. at time of inquiry	%	Number of firms *not* interested in N.R.D.C.
Modern . .	58	19	6	23	40	35
Engineering .	68	7	3	15	22	53
Textile . .	51	6	—	6	12	45
Miscellaneous .	48	6	1	14	29	34
Total . .	225	38	10	58	26	167

ii. Size-Groups

Size-Group	Total number in Group	Number of firms aware of N.R.D.C. before interview	Number of firms which had received ideas from N.R.D.C. or sent suggestions to it	Number of firms interested in N.R.D.C. at time of inquiry	%	Number of firms *not* interested in N.R.D.C.
50–99 . .	51	7	4	11	22	40
100–249 . .	80	9	3	28	35	52
250–499 . .	29	5	—	4	14	25
500–999 . .	40	9	—	6	15	34
1,000 and over	25	8	3	9	36	16
Total . .	225	38	10	58	26	167

TABLES 41–42

[*Chapter VI*]

Numbers of Firms with Library Facilities

41. by Industry Groups 42. by Size-Groups

41. BY INDUSTRY GROUPS

Facility	Numbers of firms with these facilities in the Group				
	Modern	Engineering	Textile	Miscellaneous	All groups
Total number of firms in Group	58	68	51	48	225
With internal library . . .	39 (67%)	22 (32%)	17 (33%)	18 (38%)	96(43%)
of which :					
with trained Librarian . .	5	4	1	1	11
with other full-time staff .	2	2	1	1	6
with part-time staff only .	30	10	13	5	58
with no staff	2	6	2	11	21
Periodicals circulated . . .	44	36	25	13	118
Periodicals abstracted . . .	23	15	9	7	54
External libraries used . . .	42 (73%)	32 (47%)	23 (45%)	20 (42%)	117 (52%)
of which : frequently . . .	26	14	6	11	57
occasionally . .	16	18	17	9	60

42. BY SIZE-GROUPS

Facility	Numbers of firms with these facilities in Size-Group					
	50–99	100–249	250–499	500–999	1,000 and over	All sizes
Total number of firms in Group	51	80	29	40	25	225
With internal library	13 (25%)	26 (32%)	14 (48%)	23 (58%)	20 (80%)	96 (43%)
of which : with trained Librarian	—	—	—	3	8	11
with other full-time staff	1	—	1	1	3	6
with part-time staff only	7	15	11	16	9	58
with no staff	5	11	2	3	—	21
Periodicals circulated	10	38	18	27	25	118
Periodicals abstracted	5	14	10	8	17	54
External libraries used	12 (24%)	35 (44%)	19 (65%)	30 (75%)	21 (84%)	117 (52%)
of which : frequently	4	19	8	13	13	57
occasionally	8	16	11	17	8	60

TABLE 43

[Chapter VI]

Distribution of Firms naming Various Sources of Help in Development, according to their Type of Development as Assessed by the Investigators

It is striking how closely, in the main, the proportions remain the same whatever source is claimed, suggesting that, to the firm, " development " was often something quite different from what the investigators meant. Many firms which made " no vigorous development of any kind " named sources of help in development.

The main exceptions to the constancy of proportions are :

(*a*) The high proportion of firms naming universities, that were assessed as " ideas based on Research."

(*b*) The high proportion of firms naming Research Associations, that were assessed as " ready adoption " and to a less extent " ideas based on Research," and

(*c*) The high proportion of firms naming Trade Associations, Customers and Suppliers, that were assessed as " no vigorous development of any kind."

Source of help named	Numbers of firms naming this source which were assessed as :					
	Ideas from Research	Established principles	Ready adoption	Minor innovation	No development	Total
Universities	19 (*a*)	7	2	4	9	41
D.S.I.R. and Government Laboratories	11	6	1	6	15	39
Research Associations	17 (*b*)	13	12 (*b*)	6	18	66
Consultants	9	8	2	6	8	33
Suppliers	12	18	8	9	44 (*c*)	91
Customers	7	9	2	2	22 (*c*)	42
Trade Associations	3	2	—	4	17 (*c*)	26
Friendly firms	1	4	3	1	8	17
None	9	6	2	6	22	45
All firms	44	39	19	22	101	225

Association between Vari

44. for all Firms 45. for th

The following two tables, 44 and 45, show the extent to which use of one source consult one source, and one-half consults another, then, if consulting one source does the firms will consult both.

In this table are shown those pairs of sources which go together markedly more t goes together markedly *less* than would be expected on a chance basis.

44.

Consulting Universities	Interested in National Research Development Corporation	Feels sponsored research facilities would be useful	Has internal library	Uses external library	Uses technical consultants
Consulting Universities	XX	XX	XX	XX	—
	Interested in National Research Development Corporation	XX	XX	XX	—
		Feels sponsored research facilities would be useful	XX	XX	XX
			Has internal library	XX	—
				Uses external library	XX
					Uses technical consultants

"XX" (strong association) indicates association is significant at the 1% level.
"X" (appreciable association) indicates association is significant at the 5% level.
NOTE.—A few negative associations were noted but none was significant.

ources of Information

irms only which employ Graduates

formation goes with use of another. If, for example, two-thirds of the firms of the sample ean a greater likelihood of consulting the other, it is to be expected that one-third of all

ould be expected on a chance basis. In Table 45 it is to be noted that one pair of sources

L Firms

Is a Corporate member of a learned society	Is a member of a Research Association	Consults its Trade Association on technical matters	Consults D.S.I.R. or Government laboratories	Receives help from customers	Receives help from suppliers
—	—	—	X	—	—
—	—	—	—	—	—
—	XX	—	—	—	—
XX	XX	—	—	—	—
XX	XX	—	—	—	—
X	—	XX	—	—	—
Is a Corporate member of a learned society	—	—	XX	—	—
	Is a member of a Research Association	—	—	XX	—
		Consults its Trade Association on technical matters	—	—	—
			Consults D.S.I.R. or Government laboratories	XX	—
				Receives help from customers	XX

45. FOR THOSE FIRMS

Consulting Universities	Interested in National Research Development Corporation	Feels sponsored research facilities would be useful	Has internal library	Uses external library	Uses technica consultan
Consulting Universities	X	X	X	X	—
	Interested in National Research Development Corporation	S	—	X	—
		Feels sponsored research facilities would be useful	—	—	X
			Has internal library	XX	—
				Uses external library	
					Uses technical consultan

" XX " (strong association) indicates association is significant at the 1% level.

" X " (appreciable association) indicates association is significant at the 5% level.

" NN " (strong negative association) indicates negative association is significant at the 1% level.

On account of the smaller sample in this table the criterion of significance is more stringent than in the earlier one. Those associations strengthened or only slightly weakened as a result of this but no longer significant in the smaller sample are indicated by " S."

HICH EMPLOY GRADUATES

Is a Corporate member of a learned society	Is a member of a Research Association	Consults its Trade Association on technical matters	Consults D.S.I.R. or Government laboratories	Receives help from customers	Receives help from suppliers
—	XX	—	—	NN	—
—	—	—	—	—	—
—	—	—	—	—	—
X	XX	—	—	—	—
S	XX	—	—	—	—
S	XX	X	—	—	—
Is a Corporate member of a earned society	X	—	XX	—	—
	Is a member of a Research Association	—	—	X	X
		Consults its Trade Association on technical matters	—	—	—
			Consults D.S.I.R. or Government laboratories	S	—
				Receives help from customers	S

APPENDIX 2

COPY OF *AIDE MÉMOIRE* USED PERSONALLY BY THE INVESTIGATORS

(NOTE : *This document was not treated as a questionnaire*)

1. Production of firm and of each establishment. S.I.C. Order.
   Is this a branch of a combine ? If so, state number of branches or establishments in the combine, local and otherwise.
2. Number of employees and staff at this establishment :
   Directors, non-technical. Qualifications. Highest Qualification : (*a*) Directors ; (*b*) Staff.
   Managers, non-technical.
   Office, Sales, Purchase.
   Production.
   Technical staff and employees as below.
   Total.
3. Directors, technical. Qualifications.
4. Managers, technical.
   Research Department.
   Development Department.
   Process testers, Inspectors and Works' Laboratory.
   Drawing Office or Design.
   Machinery Maintenance.
   Technical Salesmen.
5. Has the firm its own research department, here or elsewhere ?
   Has the firm its own development department, here or elsewhere ?
   Is there a full-time director or an appointed head ?
   Is the department free to decide its own subjects for research or development ?
   What are its major fields of research or development ?
6. Is the firm's research or development (*a*) a long-term programme or (*b*) *ad hoc* investigation ?
7. Has the firm or its staff recently published scientific papers or lectured on its products, developments or labour relations ? State whether (*a*) scientific, (*b*) technical, (*c*) sales and trade.
8. Can the firm give a particular example of a research or development project ? (See, also, 28.)

9. } Where do the greatest time lags in development occur?
10. } Lack of (*a*) plant, (*b*) materials, (*c*) labour and staff, (*d*) test facilities, (*e*) any other causes. How are they overcome?
11. Has any outside help been obtained in development? State if from (*a*) universities and technical colleges, (*b*) consultants, (*c*) R.As., (*d*) suppliers, (*e*) customers, (*f*) D.S.I.R. and other Government Stations, (*g*) any other sources. Results—satisfactory? inconclusive?
12. Of what research association or other bodies for co-operative research is the firm a member? State whether direct membership, benefactor membership or membership through trades association. If not interested, why?
13. Has the firm ever consulted university departments, technological colleges, technical schools, on scientific or technical matters?
    (*a*) Yes. State departments and how often.
    (*b*) No. Has firm a point of contact?
14. Has the firm ever employed consultants?
    (*a*) scientific or technical,
    (*b*) managerial,
    (*c*) building. State frequency.
15. What are the firm's thoughts on sponsored research? (*a*) have used, (*b*) would use if an institute were available, (*c*) doubtful, (*d*) would not use. Why?
16. Note any special apparatus, etc., which might be temporarily available to others or for which there is a need.
17. What are the library facilities? (*a*) full-time staff, (*a*2) is O.C. a trained librarian, (*b*) part-time staff, (*c*) textbooks only, (*d*) technical and trade literature, journals, etc., (*e*) is circulation systematic, (*f*) is abstracting done?
18. Does the firm ever use external libraries? (*a*) often, (*b*) sometimes, (*c*) is it aware of organization of such libraries?
19. What form of information service is there? (*a*) on scientific matters to customers, (*b*) on ditto to staff, (*c*) on works' views on production, etc., methods, (*d*) by house magazine, (*e*) by works' committee or council?
20. (*a*) Is it aware of the National Research Development Corporation, (*b*) has it put or received ideas, (*c*) has it used any idea, (*d*) would it *now* like to have ideas, (*e*) not interested?
21. Is there a Personnel Manager? If so, define his functions.
22. (*a*) Has there ever been trade union opposition to changes in processes or products, etc.? (*b*) Are trade unions or shop stewards always consulted before any changes are made affecting labour relations?

23. How does the firm recruit technological and scientific staff? (*a*) universities, (*b*) Technical and Scientific Register, (*c*) advertisement, (*d*) personal contacts, (*e*) any other way, such as technical colleges or schools.
24. A. Is there a scheme for training staff?
    B. Is there a scheme for improving technical education of employees? How are they encouraged to study for higher degrees, diplomas or certificates? (*a*) time off with pay, (*b*) without pay, (*c*) fees paid, (*d*) bonus for success, (*e*) promotion, (*f*) pay increase, (*g*) condition of engagement.
25. Is there any movement of staff between technical and other branches of the firm? A. no distinction; B. distinct moving; C. no movement. (*a*) Board open to firm's own scientific and/or technical men, (*b*) not open, (*c*) promotion of scientific and/or technical men from works' floor to management, (*d*) not to management.
26. Is operational research carried out in the works? If yes, classify as (*a*) full operational research, (*b*) high-grade works' management, (*c*) efficiency team studying operations, (*d*) Time and Motion Study.
27. What encouragement is given to employees to put forward ideas, (*a*) lump sum, (*b*) pay rise, (*c*) promotion, (*d*) Royalty? How valuable are suggestions?
28. Can the firm give an example of the progress of a research or development subject from initiation to the production line? How is phasing done?
29. What are the management's opinions, as members, of the services received from research associations?
    (*a*) Are visits made to and by R.A.? State frequency.
    (*b*) Are contacts on research subjects? } Obtain example.
    (*c*) Are contacts on testing, etc.? }
    (*d*) Are reports received in acceptable form?
    (*e*) State any causes of dissatisfaction.
30. Does the firm feel an unsatisfied need for technical or scientific information? If so, in what field?
31. Of what learned societies or professional bodies is the firm a corporate member?
    Of what such bodies are the directors and staff members?
    Is such membership encouraged?
    Are staff given time off to attend meetings of these societies?
    Are expenses paid?

APPENDIX 3

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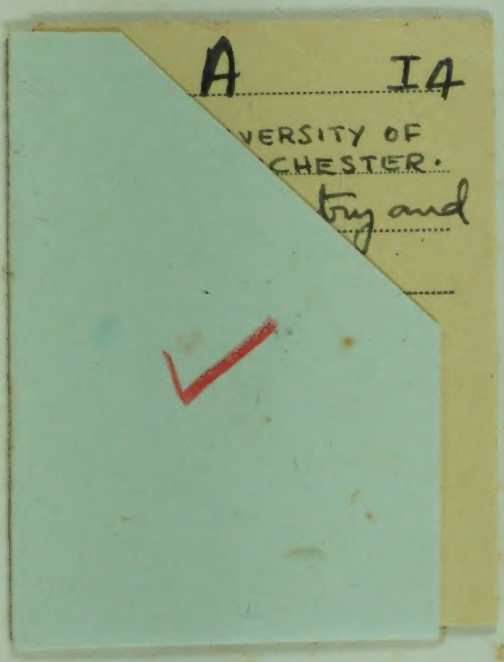
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